ABU WATER-SUPPLY.

Kudra Nala Scheme.

Printed at the Rajputana Agency Press, Mount Abu.

NOTE.

The details of measurements have been omitted in printing these estimates in order to reduce the bulk of this volume. The manuscript details are, however, filed in the Executive Engineer's Office, Mount Abu, as also are the plans.

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MOUNT ABU WATER-SUPPLY.

General Scheme and Abstract of Cost.

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MOUNT ABU WATER-SUPPLY.

GENERAL SCHEME.

REPORT.

1. *General.*—This scheme is for the provision of a piped water-supply to Mount Abu. The inhabitants of Mount Abu at present derive their water from shallow wells. Although the water in these wells is generally of good quality, there is nevertheless grave danger of pollution, both in the arrangement for drawing and in the methods of conveying it to the points of consumption. The risk in Mount Abu is especially great on account of the number of pilgrims who visit the temples at Dilwara and other places, and, in the event of cholera being imported by them, a most serious epidemic might easily result.

Apart from the great risk, another difficulty exists, *viz.*, that the wells in Mount Abu are very unreliable and many of them dry up in the hot weather. On this occurring, it has at times been found necessary to obtain water from the Nakki Lake, a manifestly dangerous proceeding since the water of the lake is in a highly polluted condition in the hot weather. Even if the lake water be utilized only for garden purposes, there still remains the danger that in spite of all precaution the same *pakhals* may be used for obtaining drinking water from the wells as are used for polluted water.

This unsatisfactory state of affairs has long been recognized, and we find that some 12 years ago a scheme was initiated for storing the rain water in an impounding reservoir at a spot about ¾th mile to the North of Mount Abu, and for distributing by pipes the water so collected. The impounding reservoir (called "Trevor Tal") was constructed, but, from a variety of causes and accidents, it failed to give the intended supply, and the scheme was regretfully abandoned.

Owing, no doubt, to this disappointment the idea of giving a proper water-supply to Abu was not again revived till now. The urgency of the demand for a plentiful supply of good water has now, however, become so imperative that the whole question has been thoroughly investigated, and, as a result of these investigations, the accompanying scheme has been prepared.

The points to be decided were, firstly, was it possible by any reasonable means to make use of the lake constructed 12 years ago? If not, would it be feasible to utilize the water in Nakki Lake (where ample storage exists), lifting it by pumps and filtering it on scientific lines, or would it be better (if possible) to find an entirely new site for an impounding reservoir which would command the station by gravity? Now it will be generally conceded that a supply from an upland source would be preferable if it can be obtained. Not only would the water be less liable to contamination than water obtained from the Nakki Lake, or from surface wells, but the heavy expenditure of pumping and filtering would be avoided; on the other hand a pumped supply would have the advantage that the engine power could at small additional expense be utilized to provide an electric lighting installation for Abu—a provision which is much needed.

The first investigations were as regards "Trevor Tal".—It was strongly felt that if a supply could by any means be obtained from this artificial lake, the scheme should be carried through even at enhanced cost, not merely because the amount of money already expended on it was considerable, but because the funds for its construction had been generously provided by His Highness the Maharao of Sirohi as a monument to his friend Colonel Trevor,

the then Agent to the Governor-General in Rajputana. The failure, of the project was unfortunately an engineering failure, and it was felt that it rested with engineers to make it good. Consequently the whole matter has been fully inquired into, but unhappily these inquiries have resulted in the definite conclusion that the utilization of this tank is impossible. The reasons which have led to this conclusion are set forth at length in Appendix 10, but it may here be stated briefly that the catchment area and storage are both quite insufficient, and that the dam itself is of such construction that nothing short of entire rebuilding would render it water-tight.

Seeing that the idea of utilizing this tank must be abandoned, inquiries have been made regarding other sources of supply. A rough scheme for obtaining water from Nakki Lake has been worked out; the estimate of the initial cost of which is Rs. 1,05,121 whilst the annual working expenses and maintenance would amount to Rs. 4,200. But it should be noted that this scheme does not include any provision for filtration,—an item which would add considerably to the prime cost and a small amount also to the working expenses.

Concurrently with the enquiries detailed above, search was made early in 1909, for a new site for a storage reservoir. A very promising site was found in the Kudra Nala, about $1\frac{1}{4}$ miles to the south-west of Mount Abu; and subsequent surveys and observations have led to the conclusion that it will amply meet the requirements of Mount Abu, and that the cost of obtaining water from this source compares favourably with any alternative proposal. A complete scheme has consequently been worked out, the details of which are set forth below.

The Kudra Nala Scheme.

2. *Amount of water required for consumption.*—Owing to the extreme dryness of the climate of Abu during nine months of the year, the rate of consumption of water is undoubtedly high. It is consequently proposed, for purposes of calculations, to adopt the "plains" allowance given in the M. W. Handbook, *viz.*, 20 gallons per diem for each European and 8 gallons for each native. No allowance is made, however, for watering horses, nor for gardens, as it is assumed that the existing wells will provide for both these contingencies; but an allowance of 25 % on other requirements has been added to meet contingencies of future growth, etc.

The population of Abu is a fluctuating one, owing to the large ingress of officials and visitors during the hot weather. At present the figures are—

During the hot weather ...	445 Europeans. 5,300 Natives.
During the remainder of the year	139 Europeans. 3,250 Natives.

Appendix 1 gives the varying requirements during the year, and shows that the consumption to be allowed for, amounts to $15\frac{3}{4}$ million gallons during the year.

The whole of the rainfall at Abu—which averages 61 inches in the year—is discharged in 3 months. But a reference to Appendix 4 shows that the rainfall has in one year (1899) fallen to only 11·29 inches. It has therefore been considered advisable in this scheme to allow a storage of $1\frac{3}{4}$ years, *i.e.*, from the conclusion of one year's rainy season to the beginning of the rainy season of the second following year, and to assume that no rain falls in the interval.

3. *Quality of water.*—The water in the Kudra Valley has been analyzed both bacteriologically and chemically. From these analyses the Divisional Sanitary Officer, 5th Division, gives the opinion that the water is perfectly pure and fit for drinking purposes without boiling.

The Divisional Sanitary Officer has also personally inspected the site of the proposed reservoir.

Details of the analyses are given in Appendix 2.

4. *General description of Scheme.*—The proposals set forth in this scheme are to store the rainfall in an impounding reservoir to be constructed in the Kudra Nala—the situation of which is shown in the General Plan (Drawing No. 1) accompanying this report—and to convey the water by gravitation to a small service reservoir to be built on a suitable site in Abu Sanitarium. Thence the water is distributed by smaller gravitation mains and branches throughout the station, with connections to principal bungalows and their cook-houses, and with standposts at convenient places for the service of the native population.

As before stated a storage of $1\frac{3}{4}$ years is contemplated, but to meet future growth in the demands for water the head works will be constructed to allow of easy expansion.

5. *The impounding Reservoir.*—The site for the impounding reservoir has not been decided upon without the fullest possible investigation, and there is every reason to believe that with careful construction of the dam, the reservoir will amply fulfil every requirement.

The Kudra stream runs generally in an easterly direction. The valley is more or less typical of all the valleys in this locality, consisting, as it does, of series of steep gorges separated by flat open meadow land, so that the erection of a dam at the head of any such gorge creates a lake of considerable magnitude. Moreover, the fact that such gorges exist, points to the conclusion that the rocks of which they are composed must be of immense strength and impermeability seeing that they have withstood for centuries the wear and tear of the heaviest floods. Hence it may be inferred that they constitute excellent sites for dam construction. The difficulty here was to find a suitable valley which would command Abu by gravity, for the plateaux on which the station is built lie comparatively high up in the chain of hills. A preliminary scrutiny of the map led to the conclusion that only four or five valleys exist within a radius of five miles which could possibly be utilised. Each of the likely valleys was prospected and the Kudra Nala was then selected as being the best available. In general character the valley is extraordinarily flat for a distance of $\frac{1}{2}$ mile above the gorge. A stream meanders through it, but there is no flow excepting during times of rain, and even then, so small is the slope that the velocity of the greatest flood does not exceed 3 feet per second. This flatness of the valley enables a lake of considerable size to be held up by a comparatively low dam.

On each side of the *Maidan* through which the stream runs, the hills rise up steeply with very little forest growth. Except for the difference in character of the vegetation, the valley resembles many a valley in North Wales or in Scotland. The *Maidan* and stream bed are sandy, but the depth of this soil is probably very small, and the rocks underlying it, as well as those composing the hills around, which rise to a height of 500 feet above the stream, are of igneous formation, mostly gneiss of extreme antiquity, but interspersed with many varieties of trap. Some of the rock is in a state of disintegration, but at the site of the gorge which it is proposed to dam, the appearance is generally sound. This rocky character of the valley is conducive to a good "run-off" and the observations carried out for determining its amount have given a very high figure indeed.

The catchment area is small, only ·251 of a square mile, but experiments show conclusively that owing to the very high proportion of "run-off" the area is more than sufficient.

The gorge itself, where it is proposed to erect a dam, is very narrow with steep rocky sides, and the top length of a dam 50 feet high (which height is more than present needs demand) is only 150 feet.

The valley is uninhabited except for one hut occupied by a native family and their 25 cattle. There is thus little sign of pollution, but it will be necessary to remove the present habitation and probably to fence in the catchment area to prevent cattle grazing and watering. The amount of clearance necessary is small, as there are but few trees in the bed of the reservoir. Grass and undergrowth may be left, or burned.

The whole of the catchment area as well as the pipe line to Abu lies

within Sirohi State, and before the project can be started it will be necessary to acquire or obtain rights over the ground.

6. Results of Survey and other observations.

Level of Tank.—A line of levels taken from a survey of India Bench Mark in Mount Abu shows that at the site of the proposed dam the level of the stream bed is 4091·25.

It is proposed to make the lowest outlet 13 feet above this, *i.e.*, at level 4104·25. The overflow of the proposed service reservoir in the Sanitarium is fixed at level 4000·00, hence there would be a minimum head of 104·25 ft. which is sufficient for all requirements.

Capacity of Reservoir.—The site of the proposed reservoir has been contoured at 10 feet intervals, and it is computed that when full to a depth of 40 feet it will contain 67,620,312 gallons. A subsequent raising of hte dam to 50 feet in height would increase the storage to 121,411,874 gallons. Appendix 8 and Drawing No. 4 have been prepared to show the computed capacity at each foot, from 10 to 40 feet above stream bed.

Catchment Area.—A careful plane-table survey of the catchment basin has been made, *vide* Drawing No. 2, and the area is computed at ·251 sq. mile. Rainfall and discharge observations show that this area is more than sufficient.

Rainfall Observations.—Rainfall was gauged daily from 26th June 1909 to 11th September 1909, at three places, *viz.*, (1) at the Executive Engineer's Office in Mount Abu (2) Trevor Tal, and (3) at Kudra Nala. The figures are detailed in Appendix 5. Now, the average annual rainfall in Mount Abu, derived from observations extending over 40 years, is 61·02 inches (*vide* Appendix 4) and during the period 26th June 1909 to 11th September 1909, the total rainfall in Mount Abu was 102·22 inches whilst that at the Kudra Nala was 112·3 inches. Hence the probable average yearly rainfall at Kudra Nala is $\frac{112\cdot3}{102\cdot22} \times 61\cdot02 = 67\cdot04$ inches. The minimum rainfall recorded in Mount Abu is 11·29 inches (1899) and it may therefore be inferred that the amount which then fell in the Kudra Nala was $\frac{67\cdot04}{61\cdot02} \times 11\cdot29 =$ 12·40 inches.

One inch of rainfall on a catchment area of ·251 sq. mile is equivalent to 583,123·2 cubic feet of water, or 3,639,520 gallons, but of course only a proportion of this enters the reservoir.

Discharge Observations.—In order to observe the discharge a temporary masonry dam with a rectangular notch was erected across the stream at a point close to the proposed site of the dam. The notch was 20 feet in length and 3 feet in height and was built with a sharp crest and sides. At the side of the dam an automatic discharge recorder was installed in a temporary shelter with a float well beneath to insure still water. The recording instrument was specially made for the purpose, and was far more delicate in its records than any ready-made instrument. Hence the results obtained may be regarded as of considerable general interest in the determination of run-off from rocky localities. For this reason the whole of the figures are appended (Appendices 6 and 7) in detail, and from these it will be observed that in a good monsoon (as was experienced in 1909) a run-off of over 82% may be counted upon. In the heaviest storm (August 3rd, when nearly 20 inches of rain fell during 24 hours) the notch in the weir and the recording instrument were insufficient to register the whole of the run-off. Also, towards the end of the monsoon, considerable leakage in the float well began to manifest itself. Hence the total amount of discharge as recorded is actually somewhat less than the real discharge.

From the observations, a total discharge of 53 million cubic feet was recorded during a total rainfall of 112 inches. As the capacity of the tank (from lowest outlet to overflow) would be $10\frac{2}{3}$rd million cubic feet, the rainfall of 112 inches would have filled the tank 5 times over.

But we have seen that in the driest year on record (1899) the fall amounted (probably) to only 12·4 inches. From Appendix 7 a fall of 12·4 inches represents a discharge of about $1\frac{3}{4}$ million cubic feet only, which would

be quite insufficient to fill the tank or to meet one year's consumption of water. For this reason a two years' storage is advocated in this project.

Taking the two least favourable successive years in Abu we find that—

In 1898 the rainfall was 33·73 inches.
" 1899 " 11·29 "

At Kudra Nala the corresponding rainfall was, by analogy—

In 1898 the rainfall was 37·04 inches.
" 1899 " 12·40 "

Even had the tank been empty to lowest outlet level at the commencement of the rains in 1898 (which is unlikely) that year's rainfall would have yielded 16 million cubic feet which would have more than filled the tank. Then at the commencement of the rains of 1899 the tank would still have contained 31 feet depth of water (*vide* Appenedix 9, Statement B) which is equivalent to 31,600,000 gallons or 5 millions cubic feet (Appendix 8). To this the rainfall of 1899 would have added 1¾ million cubic feet, making up a total of 6¾ million cubic feet to last for one year. The level of the water would then be 34½ feet above bed of tank, which from Appendix 9, Statement B, is much more than sufficient to last out till the next rains. Now, if the dam were subsequently raised to 50 feet in height, the capacity above lowest outlet would be 120½ million gallons=19¼ million cubic feet. It would then require a rainfall of about 43 inches to fill the tank which is still below the average rainfall.

In the average year, with a rainfall of 67 inches we may expect (from Appendix 7) a discharge of about 36 million cubic feet which would fill the tank 3½ times.

A rainfall of about 27 inches would generally suffice to fill the tank, if it had been previously emptied to lowest outlet level.

From the foregoing it is clear that the valley will yield an ample supply of water. The only doubtful factor is the loss which may result from leakage. Careful construction must be relied upon to reduce this loss to a minimum.

Evaporation.—No local records are available to give the evaporation in Mount Abu. Observations are now in progress but they cannot be completed for a year and for the purpose of this ~~object~~ the figures adopted (in Appendix 9) are those for the plains of Rajputana; they are presumably in excess, and the computations are therefore probably well on the safe side.*

7. *Fencing of Catchment area.*—The catchment area ought to be fenced or hedged to prevent pollution by men or animals. The wild cactus grows freely in the locality, and it is proposed to form a hedge out of this round the area. Such a hedge is impenetrable, is cheap initially, and costs little to maintain after it has become well established.

8. *The Dam and arrangements for control.*—The dam will be 40 feet in height from present stream-bed to overflow level, and the overflow will be over the entire length of the crest of the dam. The dam itself is to be of masonry (Abu Road stone facing with concrete hearting) and will be arched in plan.

As regards the height proposed for the dam, Appendix 9, Statement B, is a computation showing that 40 feet is sufficient for 1¾ years' consumption and evaporation.

Details of the proposed dam and calculations for its strength are given in the detailed project for the dam, but it may here be remarked that special arrangements have been designed for the outlets to enable the whole to be everywhere accessible. Three outlets are provided, two at low-level (*i.e.*, 13 feet above present stream-bed) and one at 10 feet higher up. The introduction of two outlets at the low-level is unusual, but it is considered essential in the case of a reservoir where the supply may have to hold out for 2 years. In the event of one of the low-level outlets becoming deranged at the time when the water level is lower than the high level outlet, the second low-level outlet will still remain available for use, thus enabling the service reservoir within the Station to be of very small capacity (one day's supply).

The whole of the outlet piping is 8″ in diameter whereas the gravity

* NOTE.—Subsequent observations show an evaporation of 3·93 feet in the 9 dry months. This is considerably under the figure taken in the project (*viz.*, 5·81 feet) and is therefore well on the safe side.

main need be only 4″. It is considered advisable to adopt this large size for the outlets in order to meet future enlargement of the scheme, for it would be extremely difficult to alter the main valves, etc., afterwards.

The dam carries a 6 feet roadway over it, and at a short distance below the dam site (outside the Catchment area) there will be a chowkidar's hut alongside the main meter.

9. *The Pipe Line.*—The total length of the gravity main is just over 2 miles. In section the line assumes the form of an inverted syphon; there being a fall of about 370 feet followed by a rise of 266 feet, leaving an actual head of 104 feet at the service reservoir. For the higher portion of the main, where the pressure is below that due to 250 feet head, ordinary cast-iron pipes are specified; but for the lower portion, where the pressure is greater, and on main roads, it is proposed to employ steel pipes, which are moreover cheaper than cast iron. (The reason that steel pipes are not used throughout is that they do not lend themselves to the sharp curves on hill sides as they cannot be bent).

The plans and sections attached to the project for the pipe line show that for about half the distance the main will be laid under existing (Imperial) roads. For the remaining portion it is proposed to cut a 6 feet roadway under which the pipe will be laid. A ruling gradient of 1 in 8 has been adopted for this roadway, which is essential for the transport of materials to the site of the dam and for future access to the head works.

10. *The Service Reservoir.*—It is considered sufficient to give a reserve of only one day's supply in a service reservoir divided into two equal compartments. If considered necessary a bye-pass can easily be given to admit of a direct service from the storage tank, but this has not been provided for in the scheme.

The proposed service reservoir is a masonry structure, partly underground, and situated on a commanding eminence in the Sanitarium. The site is not as central as might be desired but there is no site sufficiently elevated in a more central position. It will command every Government building in the Station and every private residence except Alwar House, where the water can only reach the compound.

11. *The Distribution System.*—The Scheme for the distribution system is detailed in the separate project therefor, and no special remarks appear necessary except that for the protection of the bazar a certain number of fire hydrants have been given, and that it is proposed to give house connections to all Government buildings for drinking water, and to provide street standards in the bazar and other places where a supply is likely to be required. The standards in important thoroughfares will be of more ornamental design than those in less prominent positions.

12. *Total cost of Scheme.*—The total cost of the scheme is estimated at Rs. 1,08,584 (*vide* Abstract of Cost annexed). pag. 25

13. *Maintenance, working expenses and cost of water.*—The estimated cost of maintenance and the working expenses are given in Appendix 3. The cost of water works out at 5 annas 8 pies per 1,000 gallons. This rate is high for so simple a scheme, but it is inevitable in a case where the total required supply is so small. It is presumed that the charges for water will be levied through the Municipality, by means of a water-rate based on assessed rentals.

14. *Time required for carrying out the work.*—It will take 2 years to carry out the work provided that stores are available without delay.

J. B. MacGEORGE, Captain, R.E.,

Executive Engineer,
Mount Abu Division.

APPENDIX 1.

TABLE "A"

	From 1st April to 30th June, 91 days.		From 1st July to 31st March, 275 days.		
	Population.	Gallons.	Population.	Gallons.	
(1) **Sanitarium**					
Europeans, @ 20 gallons, per diem.	245	4,45,900	89	4,89,500	
Natives, @ 8 gallons, per diem.	...	......	...	...	
(2) **Municipality**					
Europeans, @ 20 gallons, per diem.	200	3,64,000	50	2,75,000	Probably an excessive estimate.
Natives, @ 8 gallons, per diem.	5,300	38,58,400	3,250	71,50,000	
	...	46,68,300	...	79,14,500	
Add—25 per cent. for unforeseen purposes and for future demands.	...	11,67,075	...	19,78,625	
		58,35,375	...	98,93,125	
	Total ...	1,57,28,500	...	...	Gallons per annum

APPENDIX 2.

REPORT ON WATER.

From—The Medical Officer-in-charge, 5th Divisional Laboratory, Mhow
To—The Senior Medical Officer, Mount Abu.

Report on a sample of water sent by the Executive Engineer, Mount Abu. Source of water and Kudra Nala stream. Samples A and B.

Condition of surroundings good. Nala is 2 miles from town at an elevation of 5,000 feet strata basalt trap, one native crofter lives with his cows at a distance of 560 yards above the water shed area.

Collected 13th August 1909. Examined 18th August 1909 and following days.

Physical characters—

Suspended matter—present.
Colour—white.
Taste—palatable
Sediment—present.
Lustre—good.
Smell—none.

Chemical Analysis—

Reaction—neutral
Permanent hardness,—5 parts per 1,00,000.
Hardness—17 parts per 1,00,000.
Temporary hardness,—12 parts per 1,00,000
Chlorides—2-49 „ „

Sulphates—trace.
Nitrites—*nil.*
Nitrates—21 of N, per 1,00,000
Ammonia free—*nil.*
Albumenoid—·00,494, per 1,00,000
Oxidisable matter, @ 80° F—·0,870 per 1,00,000
Metals—*nil.*

Microscopic Examination of sediment—
Vegetable debris, paromesia and diatoms.

Bacteriological Examination—

Owing to faults of delivery and distance required to travel, these samples could not be examined for six days after collection. Bacteriological results can therefore not be relied on.

The samples collected above stream gave B Coli in 10 cc.
Colonies on Agar in 24 hrs. with $\frac{1}{2}$ cc. at 40°c=202 and 208.
Samples collected below—
B Coli in 5 cc.
Colonies as above=273 and 220.

Opinion.—From the combined analysis there is no doubt that this water is perfectly pure and fit for drinking purposes without boiling.

So long as the watershed area is reasonably well protected, it should remain so. The hardness (17 parts per 1,00,000) is not excessive.

The presence of B Coli in a surface water can be ignored.

MHOW: (Sd.) N. FAICHNIE, MAJOR, R.A.M.C.,

Augus 31st, 1909. *Divisional Sanitary Officer.*

APPENDIX 3.

Estimate of Cost of Water to the Consumer.

(1) INTEREST—
$3\frac{1}{2}$ per cent. on capital cost $= \frac{3\frac{1}{2}}{100} \times 1,00,000 =$ Rs. 3,500 per annum.

(2) MAINTENANCE—

(a) Mains and branches—			
1 Pipe Mistri, @ Rs 25, per month	=	300 per annum.	
2 Gangmen, @ Re. 0-4-0, per day	=	180 ,, ,,	
(b) Buildings—			
Annual and Special Repairs, @ 2 per cent., on capital cost of buildings $= \frac{2}{100} \times 46,000$	=	920 ,, ,,	
(c) Road—			
Annual and Special Repairs (say)	...	200 ,, ,,	
(d) Taps and Meters ,, ,, ,,	...	100 ,, ,,	
			1,700

(3) WORKING EXPENSES—

2 Chowkidars, @ Rs. 10, per month	=	240	
1 Meter-reader, @ Rs. 20, per month	=	240	
			480
TOTAL	=	Rs.	5,680

The estimated consumption is 16,000,000 gallons, per annum, hence the cost to the consumer will be—

Rs. $\frac{1,000}{16,000,000} \times 5,680 =$ Re. 0-5-8 per 1,000 gallons.

APPENDIX 4.

Record of Rainfall at the Mount Abu Observatory, from the year 1869 *to* 1908.

1869	...	87·38
1870	...	52·03
1871	...	47·08
1872	...	58·42
1873	...	35·99
1874	...	71·04
1875	...	144·35 max.
1876	...	43·07
1877	...	20·34
1878	...	70·07
1879	...	71·52
1880	...	49·23
1881	...	102·22
1882	...	58·89
1883	...	49·53
1884	...	93·35
1885	...	36·24
1886	...	59·61
1887	...	77·84
1888	...	43·40
1889	...	58·69
1890	...	64·63
1891	...	42·04
1892	...	100·46
1893	...	130·39
1894	...	79·85
1895	...	50·35
1896	...	56·95
1897	...	57·93
1898	...	33·73
1899	...	11·29
1900	...	49·79
1901	...	Not available.
1902	...	30·49
1903	...	47·47
1904	...	17·38
1905	...	38·42
1906	...	59·62
1907	...	79·02
1908	...	129·98

Average for a number of years is 61·02.

(Sd.) E. BURNSIDE, MAJOR, R.A.M.C.,

Senior Medical Officer.

APPENDIX 5.

Rainfall Observations, 1909.

Date.		Rainfall (inches). At Executive Engineer's office.	At Trevor Tal.	At Kudra Nala.	Remarks.
June ...	26	0·05	0·00	0·03	
	27	0·00	0·00	0·00	
	28	1·49	0·49	1·57	
	29	0·12	0·09	0·30	
	30	0·17	0·08	0·59	
July ...	1	0·01	0·02	0·01	
	2	0·07	0·01	0·08	
	3	0·00	0·00	0·00	
	4	0·07	0·02	0·03	
	5	1·20	0·62	1·27	
	6	0·05	0·06	0·14	
	7	0·03	0·00	0·29	
	8	0·17	0·07	0·21	
	9	0·01	0·04	0·09	
	10	1·23	0·41	2·82	
	11	0·23	0·33	0·18	
	12	0·93	2·19	0·58	
	13	0·15	0·02	0·27	
	14	0·23	0·43	1·79	
	15	1·35	1·40	1·00	
	16	8·66	3·76	4·30	
	17	11·95	7·79	10·31	
	18	10·90	8·29	10·15	
	19	9·95	9·24	8·78	
	20	0·02	0·12	0·04	
	21	0·09	0·18	0·25	
	22	0·04	0·07	0·09	
	23	0·00	0·00	0·00	
	24	0·02	0·00	0·02	
	25	0·18	0·46	0·12	
	26	0·20	0·13	0·23	
	27	0·52	0·82	2·40	
	28	3·10	2·94	4·50	
	29	3·46	4·21	1·94	
	30	6·99	7·02	5·97	
	31	0·35	0·41	0·52	
August ...	1	0·88	1·30	0·43	
	2	0·37	0·68	0·53	
	3	11·90	7·97	19·88	
	4	5·19	4·18	7·75	
	5	0·32	1·08	0·52	
	6	0·09	0·16	0·18	
	7	0·00	0·03	0·03	
	8	0·00	0·00	0·02	
	9	0·00	0·00	0·00	
	10	0·07	0·50	0·06	
	11	0·04	0·07	0·03	
	12	0·06	0·08	0·10	
	13	0·02	0·02	0·07	
	14	0·36	0·32	0·36	
	15	0·51	0·42	0·65	
	16	0·76	0·79	0·47	
	17	0·66	0·84	0·73	
	18	0·83	0·98	0·74	
	19	0·16	0·25	0·14	
	20	0·24	0·36	0·37	
	21	0·53	0·65	0·69	
	22	0·00	0·00	0·00	
	23	0·17	0·19	0·20	

APPENDIX 5—*(Contd.)*

Rainfall Observations, 1909—(Contd).

Date.		Rainfall (inches).			Remarks.
		At Executive Engineer's office.	At Trevoi Tal.	At Kudra Nala.	
August ... *(Contd.)*	24	0·14	0·25	0·17	
	25	1·95	1·50	1 53	
	26	0·16	0·75	0·30	
	27	0·55	0·80	0·57	
	28	1·29	0·91	1·19	
	29	0·44	0·69	0·54	
	30	0·18	0·23	0·12	
	31	0·52	0·38	0·73	
September ...	1	0·38	0·37	0·34	
	2	0·05	0·15	0·07	
	3	0·00	0·00	0·00	
	4	0·49	0·46	0·41	
	5	0·29	0·17	0 20	
	6	0·39	0 27	0 36	
	7	1·24	0·90	1·29	
	8	1·49	2·89	1·92	
	9	3·95	3·66	4·10	
	10	2·15	2·22	3·29	
	11	0·01	0·03	0·05	

APPENDIX 6.

KUDRA NALA.

Daily Register of Rainfall and Observed Discharge.

Note.—1″ Rainfall on catchment area of ·251 square mile gives $\frac{\cdot251 \times 27878400}{12}$ cubic feet =583,123·2 cubic feet of water.

Date.		Rainfall. Inches	Rainfall. Cubic feet.	Observed Discharge. Cubic feet.	Remarks.
June	26	0·03	17,494	*Nil.*	Instrument erected on 25-6-09.
	27	0·00	......	*Nil.*	
	28	1·57	9,15,503	1,15,766	
	29	0·30	1,74,937	28,800	
	30	0·59	2,94,043	71,935	
July	1	0·01	5,831	21,600	
	2	0·08	46,650	*Nil.*	
	3	0·00	......	*Nil.*	
	4	0·03	17,494	*Nil.*	
	5	1·27	6,80,566	78,678	
	6	0·14	81,637	56,600	
	7	0·29	1,69,106	9,600	
	8	0·21	1,22,456	55,550	
	9	0·09	52,481	18,000	
	10	2·82	16,44,407	8,18,250	
	11	0·18	1,04,962	2,58,400	
	12	0·58	3,38,211	1,18,173	
	13	0·27	1,54,433	88,230	
	14	1·79	10,43,791	3,69,552	
	15	1·00	5,83,123	4,88,460	
	16	4·30	25,07,430	20,97,360	
	17	10·31	60,12,000	50,67,420	
	18	10·15	59,18,700	54,81,600	
	19	8·78	51,19,822	47,54,820	
	20	0·04	23,325	2,30,100	
	21	0·25	1,45,781	42,945	
	22	0·09	52,481	*Nil.*	
	23	0·01	5,831	*Nil.*	
	24	0·02	11,662	*Nil.*	
	25	0·12	69,975	7,200	
	26	0·23	1,34,118	17,280	
	27	2·40	13,99,496	32,82,405	
	28	4·58	26,24,054	19,40,790	
	29	1·94	11,31,259	17,58,030	
	30	5·97	34,81,246	40,34,715	
	31	0·52	3,03,224	5,08,860	
August	1	0·43	2,40,743	2,65,500	
	2	0·53	3,09,055	2,13,225	
	3	19·88	105,92,491	91,89,705	Diagram incomplete owing to excessive flood.
	4	7·75	45,19,205	27,75,120	
	5	0·52	3,03,224	2,16,563	
	6	0·18	1,04,962	81,000	
	7	0·03	17,493	90,360	
	8	0·02	11,662	21,610	
	9	0·00	......	5,400	
	10	0·06	34,987	5,400	Leakage in float well hence discharge observed is lower than actual.
	11	0·03	17,493	*Nil.*	
	12	0·10	58,312	*Nil.*	
	13	0·07	40,819	*Nil.*	
	14	0·36	2,09,924	*Nil.*	
	15	0·65	3,79,030	25,875	
	16	0·47	2,74,068	1,08,000	
	17	0·73	4,25,680	2,97,600	
	18	0·74	4,38,511	3,38,100	
	19	0·14	81,637	1,56,600	
	20	0·37	2,15,750	76,888	
	21	0·69	4,02,355	1,49,205	

APPENDIX 6—*(Contd.)*

Date		Rainfall.		Observed Discharge	Remarks.
		Inches.	Cubic feet.	Cubic feet	
	22	0·00	... ..	48,600	
	23	0 20	1,16,624	1,08,000	
	24	0·17	99,131	*Nil*	
	25	1·53	8,92,178	6,94,650	
	26	0·30	1,74,937	2,59,500	
	27	0·57	3,32,380	85,110	
	28	1·19	6,93,917	3,90,150	
	29	0·54	3,15,007	4,64,400	
	30	0·12	69,975	1,90,350	
	31	0·73	4,25,680	88,275	
September	1	0·34	1,98,262	1,39,500	
	2	0·07	40,819	24,300	
	3	0 00	. .	5,400	
	4	0·41	2,39,081	5,850	
	5	0·20	1,16,624	5,400	
	6	0 36	2,09,924	28,800	
	7	1·29	7,52,229	2,13,109	
	8	1·92	11,29,597	5,35,321	
	9	4·40	25,65,742	22,91,123	
	10	3·29	19,18,475	13,56,300	
	11	0·05	29,156	1,13,644	

APPENDIX 7.

KUDRA NALA.

Progressive totals, Rainfall, Discharge, and Run-Off.

Date 1909.		Rainfall.		Observed Discharge.	Run off $\frac{\text{Discharge}}{\text{Rainfall}}$ over catchment
		Inches.	Cubic feet.	Cubic feet.	
June	26	0·03	17,494	*Nil.*	......
	27	0·03	17,494	*Nil.*	......
	28	1·60	9,32,977	1,15,766	·124
	29	1·90	11,07,931	1,41,566	·130
	30	2·49	14,01,977	2,16,501	·154
July	1	2·50	14,07,808	2,38,101	·169
	2	2·58	14,54,458	1,38,101	·164
	3	2·58	14,54,458	2,38,101	·164
	4	2·61	14,71,952	2,38,101	·162
	5	3·88	21,52,518	3,16,776	·147
	6	4·02	22,31,155	3,73,376	·167
	7	4·31	24,03,261	3,82,976	·159
	8	4·52	25,25,717	4,38,526	·173
	9	4·61	25,78,198	4,56,526	·177
	10	7·43	42,22,605	12,74,776	·302
	11	7·61	43,27,567	15,33,176	·354
	12	8·19	46,65,778	16,51,349	·354
	13	8·46	48,20,221	17,39,579	·361
	14	10·25	58,64,012	21,09,131	·359
	15	11·25	64,47,135	25,97,591	·403
	16	15·55	89,54,565	46,91,951	·513
	17	25·86	1,49,66,565	97,62,371	·652
	18	36·01	2,08,85,265	1,52,43,971	·730
	19	44·79	2,60,05,087	1,99,98,791	·769
	20	44·83	2,60,28,412	2,02,28,891	·777
	21	45·08	2,61,74,193	2,02,71,836	·774
	22	45·17	2,62,16,674	2,02,71,836	·773
	23	45·18	2,62,22,508	2,02,71,836	·773
	24	45·20	2,62,34,167	2,02,71,836	·772
	25	45·32	2,63,04,142	2,02,79,036	·775
	26	45·55	2,61,38,260	2,02,96,316	·768
	27	47·95	2,78,37,756	2,35,78,721	·883
	28	52·45	3,04,61,810	2,55,19,511	·838
	29	54·39	3,15,93,069	2,72,77,541	·863
	30	60·36	3,50,74,315	3,13,12,256	·893
	31	60·88	3,53,77,539	3,18,21,116	·899
August	1	61·31	3,56,18,282	3,20,86,616	·901
	2	61·84	3,59,27,337	3,22,99,841	·890
	3	81·72	4,68,19,828	4,14,89,556	·893
	4	89·47	5,10,39,033	4,46,24,676	·874
	5	89·99	5,13,42,257	4,48,41,239	·873
	6	90·17	5,14,47,219	4,49,22,239	·873
	7	90·20	5,14,64,712	4,50,12,599	·874
	8	90·22	5,14,76,374	4,50,34,209	·875
	9	90·22	5,14,76,374	4,50,39,609	·875
	10	90·28	5,15,11,361	4,50,45,009	·874
	11	90·31	5,15,28,854	4,50,45,009	·874
	12	90·41	5,15,87,166	4,50,45,009	·873
	13	90·48	5,16,27,985	4,50,45,009	·872
	14	90·84	5,18,37,909	4,50,45,009	·869
	15	91·49	5,22,16,939	4,50,60,884	·863
	16	91·96	5,24,91,007	4,51,68,884	·865
	17	92·39	5,29,16,687	4,54,66,484	·859
	18	93·43	5,33,55,198	4,58,01,584	·859
	19	93·57	5,34,36,835	4,59,61,184	·860
	20	93·94	5,36,52,591	4,60,38,072	·858
	21	94·63	5,40,54,946	4,61,87,277	·854
	22	94·63	5,40,54,946	4,62,35,877	·855
	23	94·83	5,41,71,570	4,62,46,677	·854

APPENDIX 7—*(Contd.)*

Date 1909.		Rainfall.		Observed Discharge.	Run off $\frac{\text{Discharge}}{\text{Rainfall.}}$
		Inches.	Cubic feet.	Cubic feet.	
	24	95·00	5,42,70,701	4,62,46,677	·852
	25	96·53	5,51,62,879	4,69,41,327	·853
	26	96·83	5,53,37,816	4,72,00,827	·853
	27	97·40	5,56,70,196	4,72,85,937	·850
	28	98·59	5,63,64,113	4,76,76,087	·844
	29	99·13	5,66,79,120	4,81,40,487	·849
	30	99·25	5,67,49,095	4,83,30,837	·852
	31	99·98	5,71,74,715	4,84,19,112	·847
September ...	1	100·32	5,73,73,037	4,85,58,612	·847
	2	100·39	5,74,13,856	4,85,82,912	·846
	3	100·39	5,74,13,856	4,85,88,312	·846
	4	100·80	5,76,52,937	4,85,94,162	·843
	5	101·00	5,77,69,561	4,85,99,562	·841
	6	101·36	5,79,79,485	4,86,28,362	·839
	7	102·65	5,87,31,714	4,88,41,471	·832
	8	104·57	5,98,61,311	4,93,76,792	·825
	9	108·97	6,24,27,053	5,16,67,915	·828
	10	112·26	6,43,45,528	5,30,24,215	·824
	11	112·31	6,43,74,684	5,31,37,859	·825

APPENDIX 8.

KUDRA RESERVOIR.

Showing Capacity at each 1 foot contour from 10 to 40 feet, derived from Drawing No. 4.

Reservoir full up to	Capacity.
10 feet	456,875 gallons (actual contour.)
11 do.	501,000 do.
12 do.	701,000 do.
13 do.	1,000,000 do. (level of lowest outlet.)
14 do.	1,300,000 do.
15 do.	1,550,000 do.
16 do.	2,000,000 do.
17 do.	2,500,000 do.
18 do.	3,150,000 do.
19 do.	3,950,000 do.
20 do.	4,977,187 do. (actual contour.)
21 do.	6,750,000 do.
22 do.	8,800,000 do.
23 do.	11,000,000 do.
24 do.	13,000,000 do.
25 do.	15,500,000 do.
26 do.	18,000,000 do.
27 do.	20,600,000 do.
28 do.	23,300,000 do.
29 do.	26,000.000 do.
30 do.	28,930,937 do. (actual contour.)
31 do.	31,600,000 do.
32 do.	34,600,000 do.
33 do.	38,000,000 do.
34 do.	41,700,000 do.
35 do.	45,600,000 do.
36 do.	49,700,000 do.
37 do.	54,000,000 do.
38 do.	58,350,000 do.
39 do.	62,900,000 do.
40 do.	67,620,312 do. (actual contour.)

APPENDIX 9.

Calculations for height for Dam.

The dam is calculated to give $1\frac{3}{4}$ years' storage, *i.e.*, the assumption is made that during one particular year *no rain* whatever falls, except just sufficient to make good the evaporation of July, August, and September of that year (which amount will be very small indeed, as in these months there will be almost continuous cloud).

Appendix 8 has been prepared to show the calculated capacity of the reservoir at each foot in depth from 10 to 40 feet, *vide* also chart of capacity. (Drawing No. 4.)

Table A gives the consumption month by month, as based on the present population of Abu, plus 25%.

The evaporation figures are those determined for Rajputana. No doubt they are somewhat in excess of the figures for Abu, but as no local records are available, these have been utilized and are at any rate well on the safe side*.

*See footnote on page 5.

Now in order to determine the requisite height for the dam, it is necessary to consider how much the water level is reduced month by month from October of one year (when the tank is assumed to be full) to the end of June of the second year following, because the evaporation figures when reduced to gallons vary according to the state of fulness of the tank; for instance the number of gallons lost by 1″ evaporation when the tank is full is far greater than the number of gallons lost by 1″ evaporation when the tank is nearly empty.

By trial and error it has been found that a dam 40 feet high will impound enough water to last from October of one year to the end of June of the second year following, and to leave a balance of $2\frac{3}{4}$ million gallons as a provision against percolation and leakage. It will be observed, however, that there is no record of the rainfall ever having been nil in Abu; the minimum record is 11·29 inches which corresponds to a fall of 12·40 inches at the Kudra Valley.

The following statement B gives the actual level of the tank at the end of each month, as based on the assumption above-mentioned, and shows that a 40 feet dam is necessary.

J. B. MacGEORGE, Captain, R.E.,

Executive Engineer, Mount Abu Division.

APPENDIX 9.

(Table "A.")

Showing requirements of water month by month.

Month.		Gallons.
January ...	31 by 35,975 Gallons equal	1,115,225
February ...	29 by 35,975 „	1,043,275
March ...	31 by 35,975 „	1,115,225
April ...	30 by 64,125 „	1,923,750
May ...	31 by 64,125 „	1,987,875
June ...	30 by 64,125 „	1,923,705
July ..	31 by 35,975 „	1,115,225
August ...	31 by 35,975 „	1,115,225
September ...	30 by 35,975 „	1,079,250
October ...	31 by 35,975 „	1,115,225
November ...	30 by 35,975 „	1,079,250
December ...	31 by 35,975 „	1,115,225
	Total ...	15,728,500

APPENDIX 9.

STATEMENT B.

Statement showing the amounts that a tank, 40 feet deep, would be reduced in level each month, from consumption and evaporation, it being assumed that no rain falls in any one particular year.

NOTE.—The daily rate of consumption is 35,975 gallons from July to March; 64,125 gallons from April to June.

Month.			Level of water. 40·00.
October. (Reservoir full)	Consumption = 1,115,225 gallons.		Feet.
	From table of capacities * this is equivalent to a fall in level of	0·24	
	Loss from evaporation	0·60	
	Total fall ...	0·84	39·16
November.	Consumption = 1,079,250 gallons.		
	Equivalent to a fall of	0·23	
	Loss by evaporation	0·40	
	Total fall ...	0·63	38·53
December.	Consumption = 1,115,225 gallons.		
	Equivalent to a fall of	0·26	
	Loss by evaporation	0·28	
	Total fall ...	0·54	37·99
January.	Consumption = 1,115,225 gallons.		
	Equivalent to a fall of	0·26	
	Loss by evaporation	0·29	
	Total fall ...	0·55	37·44
February.	Consumption = 1,043,275 gallons.		
	Equivalent to a fall of	0·24	
	Loss by evaporation	0·38	
	Total fall ...	0·62	36·82
March.	Consumption = 1,115,225, gallons.		
	Equivalent to a fall of	0·26	
	Loss by evaporation	0·74	
	Total fall ...	1·00	35·82
April.	Consumption = 1,923,750 gallons.		
	Equivalent to a fall of	0·47	
	Loss by evaporation	0·94	
	Total fall ...	1·41	34·41
May.	Consumption = 1,987,875, gallons.		
	Equivalent to a fall of	0·54	
	Loss by evaporation	1·32	
	Total fall ...	1·86	32·55

*Appendix 8.

APPENDIX 9—(*Contd.*)

Month.		Feet.	Level of water 40·00.
June.	Consumption=1,923,750 gallons.		
	Equivalent to a fall of	0·64	
	Loss by evaporation	0·86	
	Total fall ...	1·50	31·05
July.	Consumption=1,115,225 gallons.		
	Equivalent to a fall of	0·37	
	Loss by evaporation	0·00	
	Total fall ...	0·37	30·68
August.	Consumption=1,115,225 gallons.		
	Equivalent to a fall of	0·37	
	Loss by evaporation	0·00	
	Total fall ...	0·37	30·31
September.	Consumption=1,079,250 gallons.		
	Equivalent to a fall of	0·37	
	Loss by evaporation	0·00	
	Total fall ...	0·37	29·94
October.	Consumption=1,115,225, gallons.		
	Equivalent to a fall of	0·41	
	Loss by evaporation	0·60	
	Total fall ...	1·01	28·93
November.	Consumption=1,079,250, gallons.		
	Equivalent to a fall of	0·39	
	Loss by evaporation	0·40	
	Total fall ...	0·79	28·14
December.	Consumption=1,115,225, gallons.		
	Equivalent to a fall of	0·41	
	Loss by evaporation	0·28	
	Total fall ...	0·69	27·45
January.	Consumption=1,115,225, gallons.		
	Equivalent to a fall of	0·43	
	Loss by evaporation	0·29	
	Total fall ...	0·72	26·73
February.	Consumption=1,043,275, gallons.		
	Equivalent to a fall of	0·41	
	Loss by evaporation	0·38	
	Total fall ...	0·79	25·94
March.	Consumption=1,115,225, gallons.		
	Equivalent to a fall of	0·46	
	Loss by evaporation	0·74	
	Total fall ...	1·20	24·74
April.	Consumption=1,923,750, gallons.		
	Equivalent to a fall of	0·88	
	Loss by evaporation	0·94	
	Total fall ...	1·82	22·92

APPENDIX 9.—(*Contd.*)

Month.			Level of water 40·00.
		Feet.	
May.	Consumption = 1,987,875, gallons.		
	Equivalent to a fall of	0·90	
	Loss by evaporation	1·32	
	Total fall ...	2·22	20·70
June.	Consumption = 1,923,750, gallons.		
	Equivalent to a fall of	1·90	
	Loss by evaporation	0·86	
	Total fall ...	2·76	17·94

Capacity of Reservoir at 17·94 ... ... 3,116,000 gallons.
The capacity at 13·00 (lowest outlet level) ... ... 1,000,000 „

Therefore balance available to provide against percolation and leakage ... ... 2,116,000 „

(Percolation at the rate of 2,116,000 gallons in 21 months is equivalent to 3,311 gallons a day, or 2·3 gallons a minute.)

APPENDIX 10.

Reasons for abandonment of Trevor Tal Scheme.

It may be well here to set down the reasons which have led to the definite abandonment of Trevor Tal, more especially as the assumption made by the Executive Engineer, who designed the works, all seemed at the time to point to the feasibility of the scheme. In his original project he stated that the catchment area was one quarter of a square mile; that with depth of 43 feet the capacity of the tank would be 50 millions gallons; that the average rainfall was 60 inches; that the "run-off" was 30 per cent. of rainfall; and that the required provision was 26½ millions gallons per annum. The quality of the water was not referred to. On the above assumptions the yield of the catchment basin would in an ordinary year amount to 65,340,000 gallons. Unfortunately these assumptions proved to be incorrect.

The first, *viz.*, that the catchment area is ¼th square mile, is erroneous. The computation was apparently taken direct from a small scale map, and a theodolite survey has now shown that the actual area is only ⅙th square mile.

As regards the available capacity of the tank, a contoured survey down to lowest sluice level shows that it is only 17 millions gallons, instead of the 50 millions gallons assumed.

The assumption as regards rainfall is again too sanguine, as careful observations during this year show that the probable average is only 53·35 inches instead of 60. (*Vide* Appendix 4.)

The assumed proportion of run-off is, however, too low. Daily observations during this year show that during the early part of the rains, *i e.*, until the tank fills up (to which time only is it possible to make calulations without the aid of an automatic discharge recorder), the run-off amounts to over 35 per cent., whilst it is certain that the proportion must be much higher during the latter part of the rainy season. (In this connection see Appendix 11.)

Lastly, as regards amount of water required for consumption, the assumed figure, *viz.*, 26½ millions gallons per annum, appears too high. From Appendix 1 with this project the yearly consumption is set at nearly 16 millions gallons.

From the foregoing it is only too clear that the observations preliminary to the scheme were unreliable.

Now if the subsequent observations and surveys be taken as correct, it remains to be shown how far the site is capable of meeting the requirements as to quantity of water. The run-off will, certainly, not be less than 50 per cent. during a normal year so the catchment area will yield $\frac{50}{100} \times \frac{53{\cdot}35}{12} \times (\frac{1}{6} \times 5{,}280 \times 5{,}280) =$ 10,328,560 c.ft. or 64,553,550 gallons in an average year. But to base conclusions on average rainfall is useless; one must take into consideration sequences of defective rainfall as shown by existing records. Appendix 4 gives the annual rainfall from the year 1869 to 1908 in Mount Abu, and it will be observed that in the year 1898 the fall was 33·73 inches, whilst in 1899 it was only 11·29 inches, both years being far below the average.

Hence as the average rainfall in Abu is 61 inches and that at Trevor Tal is 53·35 inches, the probable rainfall at Trevor Tal was $\frac{53{\cdot}35}{61} \times 33{\cdot}73$ inches $= 29{\cdot}5$ inches in 1898, and $\frac{53{\cdot}35}{61} \times 11{\cdot}29$ inches $= 9{\cdot}9$ inches in 1899. Therefore in 1898, when the proportion of run-off could certainly not have exceeded 30 per cent., the yield was $\frac{30}{100} \times \frac{29{\cdot}5}{12} \times \frac{1}{6} \times 5{,}280 \times 5{,}280$ c.ft. $=$ 3,426,720 c.ft. $=$ 21½ millions gallons (approximately). Assuming that the dam had been made high enough to store this amount, and that the draw-off to supply the town during the years was 15¾ millions gallons, this would leave a balance of only 5¾ millions gallons to meet losses by percolation and evaporation. The former loss is difficult to determine, but as regards the latter a depth of 5·81 feet (according to the Rajputana figures) would be lost in the year, and this loss would mostly occur when the tank is low. If the capacity of the tank from sluice level to 5·81 feet above it be taken (which is on the safe side for purpose

of this argument) the loss amounts to $1\frac{3}{4}$ million gallons in the year, consequently at the end of the first year the balance available (*neglecting percolation*) would be only 4 millions gallons. Then in 1899 came a rainfall of 9·9 inches which yielded about $7\frac{1}{4}$ millions gallons; hence the amount of water available for the year was $4+7\frac{1}{4}=11\frac{1}{4}$ millions gallons, which would have been quite insufficient for consumption alone, and the supply would have failed long before the advent of the rain of 1900.

On this ground alone the scheme for Trevor Tall may be rejected, and it is useless to pursue the investigations further. It could, however, be shown that the storage is entirely inadequate and that the natural configuration of the ground would not admit of a sufficient raising of the dam to obtain the requisite storage; and further it is apparent that the dam itself is so faulty both in design and construction that nothing less than wholesale rebuilding would render it watertight.

APPENDIX II.

Trevor Tal—Run-off.

On 27th June 1909, the surface of water was 25 feet above bed of tank, *i.e.*, at level 4,077 feet.

On 17th July 1909 it reached overflow level=4,095 feet.

The capacity between levels 4,095 and 4,077 is 31,92,556−15,35,630=23,76,926 cubic feet (derived from contours given by Mr. Sham Nath in 1896).

During the 20 days in question the leakage was 0·44 feet depth per week =0·63 feet per diem=1·26 feet, which, it is estimated, amounted to 94,000 cubic feet.

Therefore the amount of water that entered the tank was 23,76,926+94,000=24,70,926 cubic feet.

The rainfall during the period was read daily, and amounted to 17·83 inches in the aggregate. As the catchment area is $\frac{1}{6}$th square mile, this rainfall amounted to $\frac{2,78,78,400}{6} \times \frac{1}{12} \times 17{\cdot}83$ cubic feet = 69,03,776 cubic feet, hence the run-off $=\frac{24,70,926}{64,03,776}=35$ nearly.

But when the record was taken on 17th July 1909 the weir was overflowing 8″, and had possibly been overflowing some hours. So the run-off must have been a little greater than 35 per cent. of rainfall.

In 1896 the run-off was found by Mr. Sham Nath, Executive Engineer, to be 42 per cent. up to the 4th August.

NOTE.—In the Kudra Valley the run-off up to the 17th July was 65 per cent.

APPENDIX 12.

Cross sectional areas of KUDRA RESERVOIR at 50 feet apart.

No of cross section.	Cross sectional area in ~~equal~~ square feet of.				
	0-10 Feet contour	10-20 Feet contour.	20-30 Feet contour.	30-40 Feet contour.	40-50 Feet contour
1	200	350	600	850	1,250
2	175	350	650	1,000	1,500
3	187	400	850	1,100	1,900
4	172	400	1,050	1,600	2,000
5	112	600	1,350	2,350	3,400
6	103	1,000	2,350	3,150	3,840
7	131	900	2,400	4,600	5,100
8	86	1,410	3,350	4,500	5,350
9	50	1,120	2,950	4,150	5,170
10	44	930	2,000	3,370	4,800
11	56	370	1,550	3,400	4,800
12	56	1,120	3,110	4,800	5,950
13	30	1,170	3,270	5,100	6,650
14	28	1,200	4,100	5,650	7,850
15	25	310	1,200	2,500	4,220
16	7	300	750	1,850	3,050
17	...	200	1,000	2,100	2,980
18	...	327	1,320	2,820	3,510
19	...	262	1,230	2,250	3,180
20	...	244	1,300	2,320	2,950
21	...	225	1,200	2,100	2,830
22	...	205	1,200	2,170	3,290
23	...	156	1,300	2,250	2,940
24	...	280	1,300	2,137	3,470
25	...	125	1,300	2,380	4,120
26	...	109	1,000	2,820	5,100
27	...	94	1,000	3,800	6,800
28	...	93	1,910	5,000	6,000
29	...	87	2,700	4,450	5,250
30	...	59	2,350	4,200	5,130
31	...	38	1,850	4,600	5,500
32	...	11	1,900	5,250	6,350
33	...	...	1,800	5,950	7,100
34	...	...	180	4,655	7,900
35	...	...	80	5,400	8,200
36	...	...	150	3,370	6,583
37	...	...	20	1,196	4,030
38	...	...	...	150	1,210
39	...	...	...	...	400
40	...	...	...	...	180
	1,462	14,465	57,620	1,23,838	1,72,133

Capacity of Reservoir, at each 10 feet vertical interval.

0-10 feet Contour— Gallons.

Average of 16 cross sectional areas $=\frac{1462}{16}=91\frac{3}{8}$ square feet.

Length $=800$ feet $\therefore$ capacity $=91\frac{3}{8}\times 800=73{,}100$ cubic feet $=4{,}56{,}875$.

10-20 feet Contour—

Average of 33 cross sectional areas $=\frac{14465}{33}=438\frac{1}{3}$ square feet.

Length $=1{,}650$ feet $\therefore$ capacity $=4{,}38\frac{1}{3}\times 1{,}650=7{,}23{,}250$ cubic feet $=45{,}20{,}312$.

20-30 feet Contour—

Average of 37 cross sectional areas $=\frac{57620}{37}=1.530\frac{10}{37}$ square feet.

Length $=1{,}850$ feet $\therefore$ capacity $=1{,}530\frac{10}{37}\times 1{,}850=38{,}31{,}000$ cubic feet $=2{,}39{,}43{,}750$.

30-40, feet Contour—

Average of 39 cross sectional areas $=\frac{123838}{39}=3{,}175\frac{1}{3}$ square feet.
Length $=1{,}950$ feet $\therefore$ capacity $=3{,}175\frac{1}{3}\times 1{,}950=61{,}91{,}900$ cubic feet $=3{,}86{,}99{,}375$.

40-50 feet Contour—

Average of 40 cross sectional areas $=\frac{172133}{40}=4303\ \frac{13}{40}$ square feet
Length $=2{,}000$ feet $\therefore$ capacity $=4{,}303\ \frac{13}{40}\times 2{,}000=86{,}06{,}650$ cubic feet $=5{,}37{,}91{,}562$.

Total Capacities.

At 10 feet	...	...	... 4.56,875	gallons.
At 20 feet =	4,56,875 +	45,20,312 =	49,77,187	„
At 30 feet =	49,77,187 +	2,39,43,750 =	2,89,20,937	„
At 40 feet =	2,89,20,937 +	3,86,99,375 =	6,76,20,312	„
At 50 feet =	6,76,20,312 +	5,37,91,562 =	12,14,11,874	„

General Abstract of Expenses for Abu water-supply.

General Abstract of Expenses.	Amount.
	Rs.
(A) Clearing site of storage reservoir and hedging of catchment area	705
(B) Dam and Valve Tower at Kudra Nala	39,665
(C) Chowkidar's quarter, godown and main meter	1,522
(D) Pipe line and road	21,135
(E) Service Reservoir	12,244
(F) Distribution system	30,694
	1,05,965
(G) Establishment; Tools and Plant	2,619
TOTAL ... Rs.	1,08,584

ESTIMATE A.

Clearing site, Hedging to catchment area and Compensation.

Report.

The items taken up in this estimate are (1) clearing site of storage Reservoir, (2) hedging in the catchment area and (3) compensation.

As regards (1), the site is already fairly clear, a few large trees exist, and these will, it is understood, be removed for their value by the Forest Department of Sirohi State. Small scrub will be burned. The total cost of clearance will therefore be very small indeed.

As regards (2), it is proposed to plant a hedge of cactus all round the catchment area to protect the reservoir from pollution by man and beast. Cactus grows abundantly everywhere on the site, and forms an impenetrable hedge.

As regards (3), there is at present only one hut within the catchment area occupied by a *lok* and his cattle. It will probably be necessary to compensate him for his eviction, and a small sum is consequently provided.

Quantity or No.	Abstract of Expenses.	Rate. Rs.	A.	P.	Per.	Amount. Rs.
14,031 rft.	(1) Hedging of cactus (Thohar) to catchment area	3	0	0	p.c.	421
	(2) Clearing site for storage reservoir ...	100	0	0	L.S.	100
	(3) Compensation	150	0	0	...	150
	Total ...	...	...	...	...	671
	Add contingencies ...	5	0	0	p.c.	34
	Grand Total ...	...	...	...	...	705

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Executive Engineer, Mount Abu Division.

ESTIMATE B

The Dam

General.—This estimate is for the cost of erecting a masonry dam, with necessary outlet arrangements, across the Kudra Valley to provide storage for the Abu Water-Supply.

In the General Scheme, submitted with this estimate, a description of the project is set forth, and it is postulated that a storage of 21 months' supply is necessary, and it is further shewn that to obtain this storage a dam, 40 feet in height, is necessary up to overflow level, the lowest outlet being 13 feet above the present bed of the valley.

But as demands for water invariably tend to increase, it is proposed-to so construct the dam that it can be subsequently raised to a height of 50 feet, which will increase the gross capacity of the reservoir from 68 to 121 millions gallons. The outlet pipes are also designed to carry a far larger supply than at present necessary.

The topography of the site is dealt with in the General Scheme, and it remains here only to touch upon the actual site proposed for the dam.

Dam site.—The drawings show a cross section of the gorge at the point selected for the dam. Here the rocks on either side have every appearance of being sound, and the form of the cross section indicates the adoption of an arched masonry dam. The narrow nature of the gorge, which for years has carried a considerable volume of water coming down at high velocity during heavy rainfall, is ample evidence of the tough quality of the rock, and leads one to the conclusion that the foundations and abutments must also be of great strength.

Materials.—The arched form of dam has further been decided upon after consideration of the materials available for construction. The dam will be of Portland Cement conrete with an admixture of lime; the local granite constitutes a good aggregate and sand is available. The lime used in this district is burned from a crystalline lime stone found near Abu Road. It is in itself a poor lime, but mixed with cement and sand in the proportion of ½ lime to ½ cement to 2 parts of sand yields a mortar which is more than sufficiently strong for the work and which is more water-tight than a mortar composed of cement and sand alone.

Mortar.—The structure will no where be subjected to tensile stress, but as the tensile strength of a mortar gives a fair indication of its resistance to crushing, tests have been made for tension as well as for compression.

As regards tension ten briquettes were made from each of the following mortars, were tested at Rurki, and gave the following average results at 2½ months :—

Mortar.	Average tensile strength of 10 briquettes.
A. 1 Abu Road lime, 2 river sand	37 lbs per sq. inch.
B. ⅓ " " ⅔ Portland cement, 2 river sand.	389 " "
C. ½ Abu Road lime, ½ Portland cement, 2 river sand.	344 " "
D. 1 Portland cement, 2 river sand	741 " "

The mixtures B, C and D above were also tested for crushing, the average resistance of 3 four inch cubes of each being, at $2\frac{1}{2}$ months :—

Concrete.	Average crushing load of 3 cubes.
B. $\frac{1}{3}$ Abu Road lime, $\frac{2}{3}$ Portland cement, 2 river sand, 4 broken granite.	1·27 tons per sq. in.
C. $\frac{1}{2}$ Abu Road lime, $\frac{1}{2}$ Portland cement, 2 river sand, 4 broken granite.	1·11 ,, ,, ,,
D. 1 Portland Cement, 2 river sand, 4 broken granite	2·03 ,, ,, ,,

Now as the crushing resistance assumed in the calculations is 9 tons per sq. foot = ·0625 ton per sq. inch, it is seen that, if we use the concrete C, there would be a factor of safety of $\frac{1 \cdot 11}{\cdot 0625}$ = 18 (nearly) at $2\frac{1}{2}$ months, which is considered sufficient.

Tests for absorption have also been made with 8 inch cubes of the concretes B, C, & D. After 48 hours immersion in water it was found that—

B increased ·016 of its original weight.
C ,, ·010 ,, ,, ,,
D ,, ·012 ,, ,, ,,
Hence C appears to be the most water-tight.

The mortar C has consequently been specified for the whole of the work where there will be water pressure.

Stone.—The stone available locally is mostly granite, but varieties of trap also occur. The granite is cheaply obtainable and is sufficiently good for ballast in the concrete provided that there is not a predominance of quartz. The whole of the dam is to be faced with stone, set in mortar C. The best stone procurable in the district is the lime stone found at Abu Road. This has been specified although its cost is very high. A fairly good river sand is available at site of dam.

Calculations for thickness of Dam.—The design of arched masonry dams has been investigated by Messrs Tudsbery and Brightmore in their "Waterworks Engineering" and by other Engineers. These investigations have been co-ordinated by Captain Garrett, R.E., in his "Theory of Arched Masonry Dams," and it is proposed here to follow the methods recommended by the latter. As his publication may not be in the hands of all who scrutinize this project, it is deemed advisable to give the whole of the reasoning leading up to the formula employed by Captain Garrett.

Consider a horizontal arch acted on by water pressure on the convex side. Let A B represent a horizontal,

section of such an arch at a depth d below the surface of the water, and let the water pressure at depth d be p. Let r=radius of arch=O A=O B.

Consider an element C D subtending an angle d at the centre O. The forces acting on the element are—

(1) The resultant water pressure P acting radially. As the water pressure acts radially at every point on the circumference from C to D, then, in the limit,

$$P = pr\, dx \quad \ldots \quad \ldots \quad (1)$$

(2) The reaction R R due to the compressive stress in the arch ring, acting at each end of the element C D. These two reactions are obviously equal.

Resolving parallel to P

$$P = 2\,R\,\sin\frac{d\,x}{2}$$

$$\text{or } p\,r\,d\,x = 2\,R\,\sin\frac{d\,x}{2}$$

$$\text{whence } R = pr \text{———————————} (2)$$

In other words the compression is constant and is equal to pr.

Let Y = maximum permissible compressive stress.

$\mathbf{Y}$ = average stress throughout the thickness t of arch ring.

r = outer radius of arch

r_1 = inner radius of arch

Then $\frac{Y}{\mathbf{Y}} = \frac{2\,r}{r+r_1}$ (Rankine's "Applied Mechanics" p. 273)———(3)

Also, evidently,

$$t = \frac{p\,r}{\mathbf{Y}} = \frac{p\,r\ .\ 2\,r}{Y\,(r+r_1)} \text{ (from (3))}$$

and

$$r_1 = r - t$$

$$\text{Therefore } t = \frac{2\,p\,r^2}{(r+r_1)} = \frac{2\,p\,r^2}{Y\,(2r-t)}$$

Solving this quadratic in t, we get

$$t = r\left(1-\sqrt{1-\frac{2\,p}{Y}}\right) \text{———————————} (4)$$

This formula is only applicable where r is constant. In many cases it would involve a great saving in masonry to vary the radius with the variations in span, but such construction would throw the face of the dam beyond the vertical and would bring unequal strains on the foundations. For these reasons it appears unlikely that r would ever be varied in practice.

Now if Z = *mean* radius of a symmetrical arch ring, P will be constant for all depths and

$$r = Z + \frac{t}{2};$$

whence from (4)

$$t = \left(Z + \frac{t}{2}\right)\left(1-\sqrt{1-\frac{2P}{Y}}\right),$$

$$\therefore t = Z\,\frac{Y}{P}\left(1-\sqrt{1-\frac{2P}{Y}}\right)^2 \text{—————} (5)$$

If for $\frac{Y}{P}\left(1-\sqrt{1-\frac{2P}{Y}}\right)^2$ we write K, the equation for the thickness of the arch becomes

$$t = K\,Z \text{—————} (6).$$

Now in this formula the only uncertain factor is Z, the degree of compression to which the work may safely be subjected. It is proposed, in the design, to use Portland cement and lime concrete faced with lime stone ashlar.

The ashlar will probably possess a crushing strength of 300—400 tons per square foot, but the concrete hearting will probably reach an ultimate strength of not more than 250 tons, and this will certainly not be attained before a year. In all probability the work will be subjected to its full stress within three months of completion and the concrete at that age will not, it is thought, stand more than say 150 tons per square foot. (*Vide* Tests quoted previously.) It is proposed to assume for the purpose of these calculations a limiting stress of 9 tons. This should give a factor of safety of 18 at 3 months. Nine tons is the lowest limit adopted by Captain Garrett in his pamphlet.

As regards r_1, the inner radius of the arch, it is shown by Captain Garrett that the most economical arc subtends (theoretically) an angle of $133\frac{1}{2}°$. But this assumes that the thickness at top is zero, whereas the effect of giving a practical width to the top of the dam is to reduce the angle. The angle adopted is 120°.

The thickness of the dam can now be computed, and it is proposed to calculate at each five feet increase of depth from 10 to 50 feet.

The value of the variable K in (6) must first be determined. We have seen that

$$K = \frac{Y}{P}\left(1-\sqrt{1-\frac{2P}{Y}}\right)^2$$

Here Y = 9 tons = 9 × 2,240 lb

and P = 62·5* × d

*Weight of one c ft. of water.

d = 10 ft.—

$$K = \frac{9\times 2240}{62{\cdot}5\times 10}\left(1-\sqrt{1-\frac{2\times 62{\cdot}5\times 10}{9\times 2240}}\right)^2$$

$$=\frac{2016}{62{\cdot}5}\left(1-\sqrt{1-\frac{62{\cdot}5}{1008}}\right)^2$$

$$=32{\cdot}26\left(1-\sqrt{{\cdot}938}\right)^2$$

$$=32{\cdot}26\left(1-{\cdot}968\right)^2$$

$$=32{\cdot}26\times{\cdot}032^2$$

$$=32{\cdot}26\times{\cdot}001024$$

$$={\cdot}0330$$

d = 15 ft.—

$$K=\frac{9\times 2240}{62{\cdot}5\times 15}\left(1-\sqrt{1-\frac{2\times 62{\cdot}5\times 15}{9\times 2240}}\right)^2$$

$$=\frac{1344}{62{\cdot}5}\left(1-\sqrt{1-\frac{62{\cdot}5}{672}}\right)^2$$

$$=21{\cdot}50\left(1-\sqrt{{\cdot}907}\right)^2$$

$$=21{\cdot}50\left(1-{\cdot}952\right)^2$$

$$=21{\cdot}50\times{\cdot}048^2$$

$$=21{\cdot}50\times{\cdot}002304$$

$$={\cdot}0495$$

For higher values of d, k is tabulated in Captain Garrett's "Theory of Masonry Dams."

For d = 20,	K = ·0660
d = 25,	K = ·0840
d = 30,	K = ·1026
d = 35,	K = ·1219
d = 40,	K = ·1420
d = 45,	K = ·1629
d = 50,	K = ·1846

Assume that the thickness of the top of the dam is 5 ft. The span at the mean radius is taken at 160 feet. Therefor Z the mean radius will be

$$\frac{160}{2 \cos 60} = 92{\cdot}38 \text{ feet.}$$

For depth = 10 feet—

$t = K\ Z$

$= {\cdot}0330 \times 92{\cdot}38$

$= 3\ 01854$ feet

Make *5′* as being the minimum amount required for roadway.

For depth=15 feet—

$t = K\ Z$

$= {\cdot}0495 \times 92{\cdot}38$

$= 457281$ feet

Make *5 feet* as before.

For depth = 20 ft.—

$t = K\ Z$

$= {\cdot}0660 \times 92{\cdot}38$

$= 6\ 09708$

$=$ *6′-2″* (say)

For depth = 25 ft.—

$t = K\ Z$

$= {\cdot}0840 \times 92{\cdot}38 = 7{\cdot}75992$ ft.

$=$ *7′-10″* (say)

For depth = 30 ft.—

$t = K\ Z$

$= {\cdot}1026 \times 92{\cdot}38 = 9{\cdot}478188$

$=$ *9′6″* (say)

For depth = 35 ft.—

$t = K\ Z$

$= {\cdot}1219 \times 92{\cdot}38 = 11{\cdot}2611$

$=$ *11′-4″* (say)

For depth = 40 ft.—

$t = K\ Z$

$= {\cdot}1420 \times 92{\cdot}38 = 13{\cdot}11796$

$=$ *13′-2″* (say)

For depth — 45 ft.—

$t = K\ Z$

$= {\cdot}1629 \times 92{\cdot}38 = 15{\cdot}048702$

$=$ *15′-1″* (say)

For depth = 50 ft.—

$t = K\ Z$

$= {\cdot}1846 \times 92{\cdot}38 = 17{\cdot}053348$

$=$ *17′-1″* (say)

The thicknesses arrived at above have been adopted, and although the dam will be built only 40 feet high in the first instance, it will be capable of being subsequently raised to 50 feet without the necessity of adding anywhere to its thickness.

In plan the curvature of the dam is constant at all depths. Still further economy might have been effected by varying the curvature from a maximum at the bottom to a minimum at the crest, but a little consideration would show that such construction would bring unequal strains on the structure, especially on the foundations, and for this reason this form has been rejected.

General design of the Dam.—As will be seen from the drawings it is proposed to carry the overflow water over the crest of the dam, to surmount the dam by a roadway carried on arches, and to concentrate the control arrangements for the outlets in a valve tower situated near the centre of the upstream face of the dam.

As great economy will be effected by adopting the arched form of dam, no expense must be spared in adopting the best materials available and the best workmanship throughout. Hence the whole of the rates entered in the estimate are as liberal as possible.

The waste weir.—The rocky nature of the stream bed obviates the necessity of providing any water cushion for the overflow. Moreover as it is proposed to give very considerable length to the weir, the weight of water flowing over even during the heaviest floods will be small.

The following calculations show that the water-way is ample:—

Calculations for Overflow Weir.

On thd 3rd August 1909, an exceptionally heavy flood was experienced in the Kudra Nala, nearly 20 inches of rain falling in 24 hours. The temporary measuring weir was overtopped and consequently the automatic discharge recorder did not give a full reading of the maximum discharge. But from a consideration of the diagram obtained the maximum discharge appears to have been in the region of 600 cubic feet per second.

This figure is nearly corroborated by using Chamier's formula

Q equals to 640 by C by R by $M^{\frac{3}{4}}$

Where Q „ discharge in cusecs
C „ co-efficient of run-off (taken here at ·8)
R „ greatest rate of rainfall per hour (taken at 4 inches)
M „ drainage area in square miles, equal to ·261

Whence Q „ 640 by ·8 by 4 by $·261^{\frac{3}{4}}$
„ 2048 by $·261^{\frac{3}{4}}$
„ 560 cusecs.

If, however, we use Dicken's formula, even with a co-efficient of 1200, the result is much less:—

D equals to 1200 by $M^{\frac{3}{4}}$

Where D „ discharge in cusecs
M „ drainage area in square miles, equals to ·261

Whence D „ 1200 by $·261^{\frac{3}{4}}$
„ 328 cusecs.

As there is no economy in restricting the effective area of the waste weir, it is proposed to extend the weir over the whole length of the dam (except where interrupted by piers and valve tower) and to assume that the velocity of approach is *nil*.

If approach velocity were to be taken into account, the necessary area of the weir would be less, but as a matter of fact the velocity of the stream is very small indeed at the point where the dam is to be constructed.

The formula for discharge (Molesworth 1904 Edn.) is

Q equals to 198·7 $E\sqrt{H^3}$

Where Q „ discharge in cubic feet per minute
E „ effective length of weir in fact, equals to Length — ·2 H
H „ Height of still water above weir in feet

The formula is equivalent to

$$D \text{ equals to } 3{\cdot}31\ E\sqrt{H^3}$$

Where D is the discharge in cusecs, equal to 600

The length of the weir is 110 feet (11 bays of 10 feet).

Substituting values :—

$$600 \text{ equals to } 3{\cdot}31 \text{ by } (110-{\cdot}2\ H) \text{ by } \sqrt{H^3}$$

Whence H equals to 1·4 feet.

The available depth of water-way over the crest up to springing of arches is 3 feet and up to crown 4 feet. As the maximum flood will produce a depth of only 1·4 feet there is a large factor of safety—especially as the crest of the weir is sloped and rounded.

Control Arrangements.—The valve-tower, culvert and control arrangements are so designed as to allow access to every working part. This matter is of vital importance to the whole scheme and no expense must be spared to secure this end.

The tower itself is, like the dam, to be built of a concrete composed of half Portland cement, half lime, two parts sand, four parts ballast, and will be faced with lime stone. To insure water-tightness a diaphragm of 24 gauge plain sheet iron is to be imbedded in the concrete, the component sheets being bolted together (not rivetted) as the concreting proceeds. The diaphragm will be pierced only by the 3 main outlet pipes. These will meet the iron sheets by specially large flanges bolted through.

It is proposed to provide 3 outlets, two at low-level, and one at high level 10 feet above the lower pair. The provision of 2 outlets at the low-level is unusual but the arrangement possesses the advantage that it will be possible to carry out repairs to either of the lower sluice valves without interrupting the supply, which would not otherwise be possible when the water level is below the higher outlet; by adopting this arrangement it is also possible to work with a much smaller service reservoir.

The lowest outlet is kept 13 feet above the present stream bed. This should be sufficient to prevent taking in muddy water.

The main sluice valves will be operated by hand wheels in the chamber above, but each inlet is further controlled by means of a specially designed plug-valves contained within the strainer. These plug-valves are operated by a chain from the balcony above, and the strainers are similarly removeable. From the general arrangement of the sluices it will be seen that the necessity for a charging pipe behind the plug-valves is obviated.

The whole of the piping is 8 inches in diameter. This is far larger than immediately necessary but in view of future enlargement of the scheme it is considered inadvisable to cut down their size, as it would be difficult to alter the pipes afterwards.

The pipe will be carried through the dam in a 3 feet culvert which is just large enough to admit of inspection. The pipe will rest on cut stone (or concrete) chairs.

On leaving the dam, the pipe at once reduces to 4 inches diameter, and, at a short distance below, a Worthington meter will be fixed, *vide* Estimate C.

Valve-house.—The valve-house will be a simple structure in stone masonry with an arched concrete roof. An outside balcony is to be provided for operating the strainers and plug-valves. Access of the interior of the valve-well is given by means of a trap door in the valve-house with an iron ladder below.

Roadway.—A roadway 6 feet in width is proposed for the pipe-line (*vide* Estimate D), and it will be continued across the dam. It will thus not only form an approach to the far side of the valley but may at a later date be extended as a short route to Gaimukh.

Arrangements for Construction of Dam.—The Kudra stream flows only during the rainy season. Hence no question of diverting flood water during construction need arise. It will however require some forethought and energetic measures to construct the dam during one working season (which is from November to the Middle of the following June.) It will of course be possible to collect material beforehand, but it is fairly certain that in November water will be met with near the foundations of the dam. During 1909 a temporary dam for gauging the flow of the stream was erected just above the site of the proposed dam. This would be useful in retaining a supply of water for the building operations, but it may also have the effect of producing a small flow of water across the site of the proposed structure below. If this occurs (as it probably will) measures must be adopted for diverting it from the section of work in progress. There is no other supply of water in the neighbourhood.

SPECIFICATION.

1. *Excavation.*—The excavation to be carefully carried out to avoid unnecessary breakage of rocks which have to remain. The amount of excavation to be done at each point will be decided by the Executive Engineer, and the assumptions made in the drawings constitute no authority to excavate to the depths shewn therein.

No concreting in foundations or abutments is to commence until the ground has been inspected and passed in detail by the Executive Engineer.

2. *Concrete.*—The whole of the concrete in the dam and valve-tower up to level of springing of road arches, to be composed as under :—

$\frac{1}{2}$ Portland cement 2 Local sand
$\frac{1}{2}$ Abu-Road lime (screened) 4 Broken stone.

The Portland cement to be in accordance with British Standard Specification.

The lime to be from Abu Road, screened through 256 meshes to the sq. inch.

The sand to be that from the bed of the Kudra Nallah, clean and unscreened.

The stone for ballast will be that procurable locally, either trap or fine granite, free from large particles of quartz. Chippings from the lime stone used for face work may be introducted with advantage. The stone to be broken to 2 inch gauge with chippings left in.

The mixing to be done in accordance with Divisional Specifications for Portland cement concrete.

The concrete is to be deposited and rammed in layers not exceeding 6 inches in depth, brought up gradually from bottom to top of dam, keeping pace with the masonry facing. As each course of masonry sets, the concrete hearting will be deposited before the subsequent course of masonry is laid in order to insure the proper filling behind the masonry.

Ordinary lime concrete, as per Divisional Specifications will be used in all situations above level of arch-springings except for roof of valve-house, which will be composed as previously described (the gauge of the ballast will, however, be 1 inch only for the roof).

3. *Stone masonry.*—The whole of the stone face work will be of Abu-Road lime stone, hammer dressed on all sides with 1 inch drafted margins on face. The masonry will be built in 1 foot courses in exact accordance with the drawings.

4. *Iron-work.*—The whole of the iron-work to be strictly in accordance with the Drawings and Divisional Specifications. The bolts in diaphragm to be $\frac{1}{4}''$ diameter, 3 inches long, and set 2 inches apart. They are to be inserted alternately from each side of the diaphragm.

5. *Wood-work.*—Wood-work as shewn in drawings to be of best Burma teak.

6. *Joinery.*—Doors to be $1\frac{1}{2}$ inch teak framed, battened and glazed and pointed, varnished, or oiled as ordered. Windows to be $1\frac{1}{2}$ inch teakwood finished as in the case of doors.

7. *Piping.*—The cast iron piping to be of standard dimensions with the exception of the special castings shown in drawings. The thickness of metal of special pipes to be the same as that of standard pipes of equal diameter.

8. *Sluice valves.*—Sluice valves to be of standard pattern with working faces in gun-metal. Wrought-iron rods, 1 inch diameter and cast iron hand-wheels, to be provided as in drawings.

9. *Pipe valves and strainers.*—Plug valves to have gun-metal seatings and faces to be attached by rings to lifting chains. Strainers to be of sheet-copper, with openings $1\frac{1}{2}$ times area of pipe. Each strainer to rest within four brass guide rods, $\frac{1}{2}$ in. diameter, fixed to the base-ring of plug valve. The plug valves must be capable of remaining fully open when the strainer is resting in position, whilst a further winding in of the chain is capable of lifting both the plug and the strainer to the surface. The free end of the lifting chain to pass over a pulley and to be secured to floor of balcony by means of a brass padlock.

Accompaniments :—

Drawings: 1. Plan, elevation and section of dam. 2. Details
Detailed estimate.

ESTIMATE ~~F~~ E

Service Reservoir.

Estimate framed by Captain J. B. MacGeorge, R. E., Executive Engineer, Mount Abu Division, of the expense of Service Reservoir for Abu Water-Supply.

Report.

General.—In connection with the general Scheme for the Water-Supply for Mount Abu, it is proposed to provide a small service reservoir to admit of repairs to the gravity main from the Storage Reservoir, being carried out. It is considered that a total of 1 day's supply will suffice for this Service Reservoir, which will, further being divided into two equal compartments of $\frac{1}{2}$ day's supply each for the purpose of making it possible to clean out or repair one compartment at a time.

Although no provision has been made in the project, it would be an easy matter to provide a bye-pass to enable the distribution mains to be supplied direct from the main from the Storage Reservoir.

The Site.—The site selected for the Service Reservoir is practically the only site available. This is a Knoll near the 20 Family Block in the Sanitarium (*vide* general plan attached to Distribution Scheme and enlarged site plan accompanying this project). From here a command is obtained over every Government building in the Station, and over every private residence with the exception of Alwar House, where the water would only reach to a point within the compound (unless this private connection were coupled direct to the gravity main from the Storage Reservoir, when a head of about 90 feet would be obtained at Alwar House).

The soil at the site is partly rock, partly hard morram. Accurate cross sections have been taken (drawings attached) to enable a close estimate to be made of the cost of excavation and walling.

Size of Reservoir.—The daily supply required during the Season is 65,000 gallons (*vide* Appendix 1 in General Scheme). Hence each compartment (half-a-day's supply) must contain $\frac{65{,}000}{2} \times \frac{1}{6{\cdot}25}$ cub. feet $= 5{,}200$ c.ft.

The depth of water from outlet to overflow will be 10 ft.; therefore each compartment must have an area of 520 s.ft. It is proposed to make the dimensions 26′ × 20′ to conform to the site and to suit constructional requirements.

The outlet is placed 3 feet above floor level, hence the total depth from bottom of tank to overflow is 13 feet.

Design of Reservoir.—The Reservoir will be a masonry structure partly under ground, with a segmental arched roof over each compartment. The outer walls will be of local stone, coursed rubble set in lime and faced with Abu-Road lime-stone. Investigations for the stability of these walls have been made graphically,—*vide* drawings No. 4, 4-A attached.

The partition wall will be of local coursed rubble set in a mortar containing equal parts of lime and cement, *vide* calculations for strength attached.

The roof arching is purposely made slightly segmental instead of semicircular, although this construction adds somewhat to the overturning moment of the two end walls, it enables the partition wall to be built without batter, eliminating as it does all danger of overturning. Had the partition wall been battered to withstand the water pressure when one tank is empty, the size of the tanks must have been increased to give the required capacity and the total cost of the Scheme would be enhanced.

The walls are to be rendered inside with $\frac{1}{2}$-inch Portland cement plaster.

The floor and foundations of walls will be a solid slab of concrete finished with Portland cement on top. It will have a total thickness of 2 feet to obviate the risk of cracking under the constantly varying load.

Access to the tanks is provided by means of end doors, approached by steps and a balcony. Windows are given for the admission of light and for

obtaining a thorough draught of air when the air is free from dust. During dusty weather however the ventilation will be obtained through air filters over the doors and windows. These air filters will consist of a 2-inch layer of cotton wool fixed between wire gauze panels.

The control arrangements for inlets, outlets, wastes and scour are clearly indicated in the drawings. The principle adopted is the independence of each tank, with combined arrangements, for overflow and scour. A connecting pipe is proposed, just below overflow level, to enable one tank to overflow into the other (if desired) before the two tanks overflow to waste. This connecting pipe would of course be closed when one tank is under repair. Ladders for access to the bottom of the tank are to be provided, and also a measuring gauge, in each tank.

Specification.

Foundations of walls and floor of tank to be a monolithic slab of lime concrete, finished with 3 inches Portland cement concrete on the surface. Both concretes to be in accordance with Divisional Specifications.

Outer walls to be composed of local stone masonry, coursed and set in lime mortar. The whole of the face work will however be of Abu-Road lime stone, hammer dressed with 1″ drafted margine, in courses not less than 1 foot in height, and set in lime mortar.

The partition wall to be of local stone, coursed masonry set in a mortar composed of $\frac{1}{2}$ Portland cement, $\frac{1}{2}$ fat lime, 2 sand. Interior of walls to be rendered with $\frac{1}{2}$ inch Portland cement mortar, brought to a fine surface.

The roof arching to be of local black stone, with voussoirs hammer-dressed to form, and set in lime mortar.

The whole of the piping to be accurately laid as in drawings, the pipes being of standard weight cast iron, with spigot and socket joints set in best blue pig lead. Flanged joints, where shown, are to be made with $\frac{1}{8}$ inch asbestos sheet, and white lead, tightly bolted up.

All sluice valves to have gun-metal working faces; those outside the building will be provided with removeable keys, those inside with suitable hand-wheels.

The outlets to have their mouths flush with the wall, and to be provided with copper wire strainers, carefully fixed thereto.

The mouths of scour pipes to be 3″ below floor line, and the whole of the flooring to be currented 3 inches towards scour.

The whole of the joinery to be 1st class teak-wood, finished with plain rounded mouldings and provided with brass furniture.

Valve pits to be of 9″ brick walling with local slab-stone covers. Each cover to have an iron lifting ring securely fixed thereto.

LIST OF ACCOMPANIMENTS.

Drawings:—

1, Site plan.
2, 2-A Cross Sections of ground (2 sheets)
3, Detailed drawings of Reservoir.
4, 4-A Graphic investigations for stability of outer walls (2 sheets).

Calculations for strength of partition wall.
Detailed estimate of cost.

ESTIMATE F.

Distribution System.

Estimate framed by Captain J. B. MacGeorge, R. E., Executive Engineer, Mount Abu Division, of the expense of the proposed distribution of Water-Supply.

Report.

This estimate is framed to cover the cost of distributing water to the Civil and Military Station, Abu, by gravity from a service reservoir placed on an eminence near the "Twenty Family Block" in the Sanitarium.

Allowance of water.—The allowance of water proposed is the "Plains" scale laid down in the Military Works Handbook, *viz.*, 20 gallons a day for Europeans and 8 gallons a day for natives.

Population.—The population at Abu is a fluctuating one, the summer population being almost double that in the winter. Table "A" gives the present population during each period, and an addition of 25 per cent. has been made to cover future demands and unforeseen contingencies. During 91 days in the summer months the amount of supply required is 58,35,375 gallons which is $= \frac{5835375}{91}$, = to 64.125 gallons per diem. It is assumed that the whole of this must be supplied in 8 hours and for the purposes of calculating the figure is taken at 65,000 gallons.

It will be observed that no allowance is made for watering animals. With the large amount of reserve allowed (*viz.*, 25 per cent.) it was thought unnecessary to do so, especially as it is probable that many of the animals will continue to be supplied from existing wells. The number of animals in Abu during the season is difficult to estimate and it is moreover open to question whether any of them would be entitled to a free supply.

Private connections.—The whole of the water required for private connections has been estimated for, but the cost of the connections themselves is not included in the estimate. These would be paid for privately, as is customary, if house-owners require them.

Calculations for size of pipes.—The calculations for size of pipes are based on the tables in the M. W. Handbook.

Appendix I. shows how it is proposed to distribute the 65,000 gallons per diem, *i.e.*, the allowance at each house or stand-post is set forth.

Appendix II. gives the size of pipe calculated on the above distribution.

Appendix III. gives the residual head at each point along the line.

Linking up of mains.—It will be observed that mains are linked up as far as considered necessary. This in many cases has tended to economy in size of piping.

Head.—The head is no where too great for ordinary C. I. pipes with lead joints; hence no relief tanks are provided. Scour valves will be given at all low points, but very few if any air valves will be necessary as the system is everywhere well relieved by bibcocks at high points.

House-meters.—All bungalows are provided with small house-meters, and provision is made for a main meter in the estimate for the Service Reservoir.

Standposts.—Standposts are given at various points for the convenience of those who have no house connections. Those situated in the main thoroughfares will mostly be of stone masonry with a suitable platform, and in some cases *massack* platforms are added. Those standposts situated away from public thoroughfares, *e g.*, in the S & T. Followers' Lines, where appearance is not an object, will consist of a simple bent rail with standpipe attached. Three standards, as shown in the plan, are of Glenfield pattern with fire hydrants for the protection of the Bazar.

Lavatories.—For Soldiers' Lavatories, ball valves will control the supply to the existing cistern.

A detail of rates for pipe laying is annexed.

Specification.

The cast iron piping will be standard weight with plain spigot and socket joints which will allow of slight adjustment to take easy curves. Joints to be run with best blue pig lead (not arsenal lead). C. I. piping to be laid 2′ 6″ below ground.

The wrought iron piping to be of standard weight, and galvanized, with ordinary collared joints. The wrought iron piping to be laid 1′ 6″ below level of ground.

Valves and fittings to be of approved manufacture.

Testing.—The whole of the C.I. piping to be tested in lengths not exceeding 300 feet to a head of 200′ before filling in the trenches. Any leaks which appear are to be made good with lead wool, properly caulked.

List of Accompaniments.

Drawings:—

1. General Plan (Blue print)
2. Skeleton Plan
3. Design of Masonry Stand-Post
4. „ „ Rail „

Tables :—

A (Population)
B (Details of piping and fittings)

Appendices :—

1. Details of supply
2. Duty of each pipe
3. Residual heads

Rate Abstracts—4″ pipe, $3\frac{1}{2}$″, 3″, $2\frac{1}{2}$″, 2″, $1\frac{1}{2}$″, 1″, and $\frac{3}{4}$″.

etc.

	Bends of Sorts. (Nos.)								G. W. I. elbows (Nos.)	D. O. Screw plugs. (Nos.)		Cast I[ron] Sluice V[alves] (No[s.])	
Iron.	Cast Iron.			Galvanized Wrought Iron									
″-¾″	4″	3½″	3″	2½″	2″	1½″	1″	¾″	¾″	1″	¾″	4″	3½
...	1	...	...	...	...	...	...	...	...	...	...	1	..
7	...	4	...	...	...	1	6	1	21	...	...	...	
3	...	3	...	...	...	...	5	...	6	1	...	...	.
1	...	...	1	...	...	...	2	...	10	...	...	...	.
9	...	...	...	8	...	...	2	4	16	...	5	...	.
2	...	...	...	4	...	...	5	1	3	...	...	...	.
...	...	...	2	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	2	2	10	...	...	...	
...	...	...	...	...	...	4	...	2	...	...	1	...	
2	...	...	...	...	...	...	...	...	8	...	...	...	
3	...	...	...	...	...	...	2	6	8	...	...	...	
...	...	...	...	...	...	...	4	...	...	...	...	...	
...	...	...	...	...	...	...	2	...	...	...	...	...	
...	...	...	...	...	...	...	3	...	2	...	...	...	
1	...	...	...	...	...	...	2	4	2	...	...	...	
...	...	...	4	...	...	...	...	...	...	...	...	...	
6	...	...	3	...	...	...	4	2	20	...	...	...	
3	...	...	...	...	...	...	2	...	2	1	1	...	
...	...	...	2	...	...	...	...	...	6	...	...	...	
9	...	...	...	...	...	...	4	...	20	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	

APPENDIX I.

Details of water to be supplied by each pipe, *vide* skeleton plan.

Pipe.	Details to be supplied.	Gallons for each detail.	Total gallons in 8 hours.	
	RED MAIN ; 8-0.			
8-7	Private connection, Sirohi House ...	1 by 200	200	
	Cemetery Standposts	......	40	
	Magistrate's Court, 40 ; Bakery, 60 ...	40 plus 60	100	
	Single Standposts	1 by 120	120	
	Private connections to 3 native houses, south of road.	3 by 10 by 8	240	
			700	
	Add—25 per cent. future increase ...	......	175	
		Total 8-7 ...		875
7-6	Private connection, Jaipur House ...	1 by 200	20	
	" " Khetri "	1 by 10 by 8	80	
	" " Alwar Vakil's House ...	1 by 6 by 8	48	
	Single Standposts near Bharatpur " ...	1 by 120	120	
	Private connection to " " ...	1 by 6 by 8	48	
	" " Sirohi Vakil's " ...	"	48	
	Adam's Hospital, and and Hospital Assistant's quarters, 25 natives.	25 by 8	200	
			744	
	Add—25 per cent. future increase ...	......	186	
		Total 7-6 ...		930
6-9	$\frac{1}{4}$ Bazar $=\frac{3000}{4}=750$ natives	$\frac{3000}{4}$ by 8	6,000	
	Add—25 per cent. future increase ...	......	1,500	
		Total 6–9 ...		7,500
9-5	$\frac{1}{2}$ Bazar $=\frac{3000}{2}=1{,}500$ natives ...	1,500 by 8	12,000	
	Private connection to "The Peaches" ...	1 by 200	200	
	$\frac{1}{8}$ Bazar $=\frac{3000}{8}$ natives	$\frac{3000}{8}$ by 8	3,000	
	1 Single Standposts at Church	1 by 120	120	
			15,320	
	Add—25 per cent. future increase ...	......	3,830	
		Total 9-5 ...		19,150
6-13	2 Double Standposts on main	2 by 240	480	
	Private connection to Sirohi Kotwal ...	1 by 6 by 8	48	
			528	
	Add—25 per cent. future increase ...	......	132	
		Total 6-13 ...		660
	Branch ; 14-13			
13-5	Private connection to "Lake House" ...	1 by 200	200	
	2 Private connection to native houses ...	2 by 6 by 8	96	
	2 Single Standposts at Chaprasis' Lines ...	2 by 120	240	
	1 S.P., in Residency servants Lines & Farm...	1 by 200	200	
	1 Single S.P., on submain	1 by 120	120	
	C.M.O's Office, 40 gallons, 6 natives and 1 private connection to native house.	$40+6\times8+6\times8$	136	
	Branch to "The Wilderness" ...	1 by 200	200	
	Connection to Telegraph Office... ...	1 by 200	200	
	Private connection, "Hurmuz Hall" ...	1 by 200	200	
	Connection to "The Dell"	1 by 200	200	
			1,792	
	Add—25 per cent. future increase ...	......	448	
		Total 13-5 ...		2,240
	Carried over ...	...	...	31,355

APPENDIX I.—*(Contd.)*

Pipe.	Details to be supplied.	Gallons for each detail.	Total gallons in 8 hours.	
	Brought over ...	......	...	31,355
5-4	Residency, excluding servants	10 by 20	200	
	Single standpost on branch	1 by 120	120	
	Agency offices, 16 natives 50 gallons ...	16 by 8 plus 50	148	
	Connection to "The Retreat"	1 by 200	200	
	Private connection to Jodhpur House ...	1 by 200	200	
			868	
	Add—25 per cent. future increase ...	......	217	
		Total 5-4 ...		1,085
4-3	Lawrence School, 74 Europeans, 20 natives...	74 by 20 plus 20 by 8	1,640	
	Private connection to "The Briars" ...	1 by 200	200	
			1,840	
	Add—25 per cent. future increase ...	......	460	
		Total 4-3 ...		2,300
9-10	$\frac{1}{8}$ Bazar = $\frac{3000}{8}$ natives	$\frac{3000}{8}$ by 8	3,000	
	Meat market	say	50	
	Private connection, Bikaner Vakil's House ...	1 by 6 by 8	48	
	2 Double standposts on main	2 by 240	480	
	1 " on branch	1 by 240	240	
	Private connection, Tonk Vakil's House ...	1 by 6 by 8	48	
			3,626	
	Add—25 per cent. future increase ...	......	906	
		Total 9-10 ...		4,532
10-3	Private connection, Tonga Terminus ...	say	280	
	" " Jal house (10 Natives) ...	10 by 8	80	
	Erinpura Barracks, 70 natives	70 by 8	560	
	Private connection, Jal Terrace, 25 natives ...	25 by 8	200	
	1 Single standpost on main	1 by 120	120	
	2 private connection "Victoria House" and "Connaught House."	2 by 200	400	
	Connection to "Mount Pleasant," "The Boulders" and "Hill Side." ...	3 by 200	600	
			2,480	
	Add—25 per cent. future increase ...	......	620	
		Total 10-3 ...		3,100
3-2	1 Single standpost on main	1 by 120	120	
	Private connection to Free Masons' Hall ...	say	60	
	Dak Bungalow	1 by 200	200	
	Private connection to "The Crags" ...	1 by 200	200	
	Roman Catholic Chapel (50 gallons) and Chaplain's quarters.	50 plus 200	250	
			830	
	Add—25 per cent. future increase ...	......	208	
		Total 3-2 ...		1,038
2-1	Connection to "Summer Hill"	1 by 200	200	
	Barracks Nos. 14, 15, 16, 9 Europeans each...	3 by 9 by 20	540	
	Quarter Guard No. 57, 100 gallons; & mineral water factory, 300 gallons.	100 plus 300	400	
	School	say	60	
	Canteen and Coffee shop (No. 35) ...	say	100	
	Lavatory for 72 men @ 10 gallons ...	72 by 10	720	
			2,020	
	Add—25 per cent. future increase ...	......	505	
		Total 2-1 ...		2,525
		Total, Red Main	...	45,935

APPENDIX I.—*(Contd.)*

Pipe.	Details to be supplied.	Gallons for each detail.	Total Gallons in 8 hours.	
	BLUE MAIN; 14-0.			
14-19	Private connections to 4 bungalows "Suntook Lodge," "Glen View," "Swinley Lodge," Dholpur House) ...	4 by 200	800	
	Single standpost	1 by 120	120	
	Private connection to "Nun Thorpe"	1 by 200	200	
			1,120	
	Add—25 per cent. future increase	......	280	
		Total 14-19 ...		1,400
	Submain; 20-19			
19-18	Private connection to "Carrick Cottage"	1 by 200	200	
	Public Works Department Workshop, 100 gallons 8 natives	100 + 8 by 8	164	
	Single standpost on main	1 by 120	120	
	Rajputana Hotel, private connection, 40 Europeans and 40 natives	40 by (20+8)	1,120	
	Executive Engineer's bungalow	1 by 200	200	
	" Office, etc., 50 gallons 20 natives...	50+(20 by 8)	210	
			2,014	
	Add—25 per cent. future increase		503	
		Total 19-18 ...		2,517
	Branch; 21-18.			
18-17	Private connection to Mr. Darashaw's house ...	1 by 200	200	
	Public Works Department Establishment quarters, 15 Europeans and 8 natives	15 by 20+8 by 8	364	
	Superintending Engineer's Superintendent's quarters and Agent Governor-General's Superintendent's quarters	2 by 150	300	
	2 Accountant's quarters	2 by 100	200	
	2 Single standposts on branch	2 by 120	240	
	Rajputana Club (private connection)— Mineral Water Factory ... ... Gallons 300 Lavatories ... ... " 60 20 Natives ... ... " 8	300+60+20 by 8	520	
	Connection to "Club Gate"	1 by 200	200	
			2,024	
	Add—25 per cent. future increase	......	506	
		Total 18-17 ...		2,530
17-16	Private connections to Alwar and Bikaner Houses ...	2 by 200	400	
	Warrant Officers quarters (S. and T.) 5 Europeans, 8 natives	5 by 20+8 by 8	164	
	Standpost in Followers' Lines	1 by 120	120	
	Slaughter house ... ... Gallons 100 Bakery .. .. " 60 Supply and Transport yard ... ... " 100	100+60+100	260	
	Single standpost on main	1 by 120	120	
			1,064	
	Add—25 per cent future increase	......	266	
		Total 17-16 ...		1,330
16-0	Station Hospital, 25 Europeans, 40 natives; Laundry 100 gallons; Operating room, 20 gallons	25 by 20+40 by 8+100+20	940	
	Cross main from 17— Private connection to "The Karundas" and "The Grange"	2 by 200	400	
	Connection to "Sandhurst"	1 by 200	200	
			1,540	
	Add—25 per cent. future increase	......	385	
		Total 16-0 ...		1,925
		Total, Blue Main	...	9,702

APPENDIX I.—*(Concld)*

Pipe.	Details to be supplied.	Gallons for each detail.	Total gallons in 8 hours.	
	GREEN MAIN; 4-1.			
4-20	Post Office, 15 natives	15 by 8	120	
	Private connection to "Midhurst"	1 by 200	200	
	1 Single standpost on main	1 by 120	120	
			440	
	Add—25 per cent. future increase	......	103	
		Total 4-20 ...		513
20-22	Private connections to—			
	The Shrubbery and Rose Cottage	3 by 200	600	
	Connection to Rock View	*1 by 200*	*200*	
			800	
	Add—25 per cent. future increase	......	200	
		Total 20-22 ..		1,000
22-1	Connection to "The Knoll"	1 by 200	200	
	No. 85, "4—Family Block", 20 Europeans, 5 natives ...	20 by 20 + 5 by 8	440	
	No. 92, "20—Family Block", 80 Europeans, 20 natives ..	80 by 20 + 20 by 8	1,760	
	Barrack Blocks Nos. 13 and 12, 9 men each ...	2 by 9 by 20	360	
			2,760	
	Add—25 per cent. future increase	......	690	
		Total 22-1 ...		3,450
		Total, Green Main	...	**4,993**
	BROWN MAIN; 24-1			
24-23	No. 69, Quarter-Master Sergeant's quarters, 5 Europeans and 5 natives	5 by (20+8)	140	
	No. 1, Barrack, 9 Europeans	9 by 20	180	
	No. 61, Staff-Sergeant's quarters, 5 Europeans and 5 natives	5 by (20+8)	140	
	No. 59, Sergeant-Major's quarters, 5 Europeans and 5 natives	5 by (20+8)	140	
	1 Single standpost on branch	1 by 120	120	
	No. 117, Lavatory for 72 men at 10 gallons each ...	10 by 72	720	
	No. 8 Barrack, 9 Europeans	9 by 20	180	
			1,620	
	Add—25 per cent. future increase	......	405	
		Total 24-23 ...		2,025
23-1	Commanding Officer's Office and orderly room ...	say	40	
	No. 34, Sergeant's Mess	"	100	
	Nos. 2, 3 and 7 Barracks for 9 men each	3 by 9 by 20	540	
	Nos. 4, 5, 6, 9, 10 and 11 Barracks for 9 men each ...	6 by 9 by 20	1,080	
	Single standpost on main	1 by 120	120	
			1,880	
	Add—25 per cent. future increase	......	470	
		Total 23-1 ...		2,350
		Total, Brown Main	...	**4,375**

APPENDIX I.—*(Concld.)*

Abstract of the foregoing.

	Gallons in 8 hours.
Red Main	45,935
Blue Main	9,702
Green Main	4,993
Brown Main	4,375
	65,005

Say 65,000 gallons per diem (8 hours).

APPENDIX II.

Duty of each pipe in train.

Pipe.	Duty.	Gallons in 8 hours.	Gallons. per minute.	Length.	Diameter of pipe.	Head absorbed in 100 feet length.	Total head lost by friction.
1	2	3	4	5	6	7	8
				Ft.	Inch.	Ft.	Ft.
		RED	MAIN.				
7-8	Direct supply	875	1·8	725	(a) 1	·90	6·5
6-7	To 7-8 = 875 Direct supply „ 930	1,805	3·7	590	1½	·54	2·99
9-6	Half of supply to 6-7 „ 903 Direct supply „ 6,000	6,903	14·4	510	2	1·6	8·16
5-9	Half of supply to 9-6 „ 3,452 Direct supply „ 19,150	22,602	47·9	810	3	2·2	17·8
13-6	Half supply to 6-7 „ 903 Direct supply „ 660	1,563	3·3	560	(b) 1	3·0	16·8
5-13	To 13-6 „ 1,563 Direct supply „ 2,240	3,803	7·9	980	2	·50	4·9
4-5	To 5-9 „ 22,602 To 5-13 „ 3,803 Direct supply „ 1,085	27,490	57·3	380	3	3·15	12·0
3-4	Half supply to 4-5 „ 13,745 Direct supply „ 2,300	16,045	33·4	460	3	1·07	4·9
10-9	Half of supply to 9-6 „ 3,453 Direct supply „ 4,532	7,895	16·6	1,310	2½	·67	11·1
3-10	To 10-9 „ 7,895 Direct supply „ 3,100	11,085	23·1	1,820	2½	1·3	23·4
2-3	To 3-4 „ 16,045 To 3-10 „ 11,085 Direct supply „ 3,100	28,168	58·7	1,170	3½	1·02	11·9
1-2	To 2-3 „ 28,168 Direct supply „ 2,525	30,693	63·9	1,360	3½	1·19	16·2
0-1	To 1-2 „ 30,693 Direct supply „ 9,338	40,031	83·4	140	4	·10	1·4
	Principal Branches.						
14-13	Direct supply ...	1,490	3·1	1,030	1	2·5	25·7
15-4	Do. ...	835	1·7	1,170	2	·02	0·2
		BLUE	MAIN.				
19-14	Direct Supply	1,400	2·9	1,900	1	2·4	45·6
19-20	½ Supply to 20-4 = 4,753 Direct supply „ 2,517	7,270	15·2	1,240	2½	·57	7·1
18-19	To 19-20 „ 7,270 Direct supply „ 1,400	8,670	18·1	250	2½	·81	2·0
17-18	To 18-19 „ 8,670 Direct supply „ 2,530	11,200	23·3	1,010	3	·52	5·2
16-17	To 17-18 „ 11,200 Direct supply „ 1,330	12,530	26·1	920	3	·65	6·0
0-16	To 16-17 „ 12,530 Direct supply „ 1,925	14,455	30·0	1,200	3	·86	10·3
	Principal Branches.						
26-18	Direct supply	2,280	4·7	590	2	1·70	1·0
27-26	Do.	500	1·1	530	1	·27	·3

(a) Make 1½″ for half distance.
(b) Eu, make 1½″ to give a compensating flow in case of break down in 9-6.

APPENDIX II.—(*Contd.*)

Duty of each pipe in train.

Pipe.	Duty.	Gallons in 8 hours.	Gallons per minute.	Length.	Diameter of pipe.	Head absorbed in 100 feet length.	Total head lost by friction.
1	2	3	4	5	6	7	8
				Ft.	Inches.	Ft.	Ft.
		GREEN	MAIN.				
20-4	To 4-5 half of 27,490 = 13,254 } Direct supply 513 }	14,258	29·7	870	3	·85	7·5
22-20	$\frac{2}{3}$ Of supply to 20-4 = 9,505 } Direct supply 1,000 }	10,505	21·4	1,180	3	·46	5·4
1-22	To 22-20 10,505 } Direct supply 3,450 }	13,955	29·1	1,350	3	·81	23·6
	Principal Branches.		*Nil.*				
		BROWN	MAIN.				
23-24	Direct Supply	2,025	4·2	720	$1\frac{1}{2}$	·60	4·3
1-23	To 23-24 2,025 } Direct supply 2,350 }	4,375	9·1	480	2	·65	3·1

APPENDIX III.

Residual Head at each point.

Point.	Residual Head.				Remarks.
1	Fall from Reservoir	...	...	= 57·07	
	Friction in 0-1	...	...	1·40	
	∴ Residual Head	...	...	,, 55·67	
2	Residual Head at 1	...	...	,, 55·67	
	Fall from 1	...	...	104·15	
				159·82	
	Friction in 1-2	...	...	16·20	
	∴ Residual Head	...	...	,, 143·62	
3	Residual Head at 2	...	...	,, 143·62	
	Rise from 2	...	...	25·78	
				117·84	
	Friction in 2-3	...	...	11·90	
	∴ Residual Head	...	...	,, 105·94	
4	Residual Head at 3	...	...	,, 105·94	
	Rise from 3	...	...	23·21	
				82·73	
	Friction in 3-4	...	...	4·90	
	∴ Residual Head	...	...	,, 77·83	
5	Residual Head at 4	...	...	,, 77·83	
	Fall from 4	...	...	14·36	
				92·19	
	Friction in 4-5	...	...	12·00	
	∴ Residual Head	...	...	,, 80·19	
13	Residual Head at 5	...	...	,, 80·19	
	Fall from 5	...	...	16·36	
				96·55	
	Friction in 5-13	...	...	4·90	
	∴ Residual Head	...	...	,, 91·65	
9	Residual Head at 5	...	...	,, 80·19	
	Fall from 5	...	...	33·32	
				113·51	
	Friction in 5-9	...	...	17·80	
	∴ Residual Head	...	...	,, 95·71	

APPENDIX III.—(*Contd.*)

Residual Head at each point.

Point.	Residual Head.				Remarks.
6	Residual Head at 9	... ...	=	95·71	
	Fall from 9	... ...		7·39	
				103·10	
	Friction in 9-6	... ...		8·16	
	∴ Residual Head	... ...	„	94·94	
6	Residual Head at 13	... ...	„	91·65	
	Fall from 13	... ...		24·35	
				116·00	
	Friction in 13-6	... ...		16·80	
	∴ Residual Head	... ...	„	99·20	Which balances 6 above.
7	Residual Head at 6	... ...	„	99·20	
	Fall from 6	... ...		10·45	
				109·65	
	Friction in 6-7	... ...		2 99	
	∴ Residual Head	... ...	„	106·66	
8	Residual Head at 7	... ...	„	106·66	
	Fall from 7	... ...		2·59	
				109·25	
	Friction in 7-8	... ...		6·50	
	∴ Residual Head	... ...	„	102·75	
10	Residual Head at 3	... ...	„	105·94	
	Fall from 3	... ...		68·75	
				174·69	
	Friction in 3-10	... ...		23·40	
	∴ Residual Head	... ...	„	151·29	
9	Residual Head at 10	... ...	„	151·29	
	Rise from 10	... ...		44 28	
				107·01	
	Friction in 9-10	... ...		11·10	
	∴ Residual Head	... ...	„	95·91	Which balances 9 above.
14	Residual Head at 13	... ...	„	91·65	
	Fall from 13	... ...		14·73	
				106·38	
	Friction in 13-14	... ...		25·70	
	∴ Residual Head	... ...	„	80·68	

APPENDIX III.—(*Contd.*)

Residual Head at each point.

Point.	Residual Head.				Remarks.
15	Residual Head at 4 ...	...	=	77·83	
	Friction from 4 to branch ...	...		8·00	(say)
	∴ Residual Head at take off	...	,,	69·83	
	Rise in branch ...	...		66·00	
				3·83	
	Friction in branch ...	...		·20	
	∴ Residual Head ...	...	,,	3·63	
16	Fall from Reservoir ...	...	,,	65·04	
	Friction in 0-16 ...	...		10·30	
	∴ Residual Head ...	...	,,	54·74	
17	Residual Head at 16 ...	...	,,	54·74	
	Fall from 16 ...	...		2·14	
				56·88	
	Friction in 16-17 ...	...		6·00	
	∴ Residual Head ...	...	,,	50·88	
18	Residual Head at 17 ...	...	,,	50·88	
	Fall from 17 ...	...		10·83	
				61·71	
	Friction in 17-18 ...	...		5·20	
	∴ Residual Head ...	...	,,	56·51	
19	Residual Head at 18 ...	...	,,	56·51	
	Fall from 18 ...	...		7·22	
				63·73	
	Friction in 18-19 ...	...		2·00	
	∴ Residual Head ...	...	,,	61·73	
20	Residual Head at 19 ...	...	,,	61·73	
	Fall from 19 ...	...		50·91	
				112·64	
	Friction in 19-20 ...	...		7·10	
	∴ Residual Head ...	...	,,	105·54	
26	Residual Head at 18 ...	...	,,	56·51	
	Rise from 18 ...	...		31·93	
				24·58	
	Friction in 18-26 ...	...		1·00	
	∴ Residual Head ...	...	,,	23·58	

APPENDIX III.—(*Concld.*)

Residual Head at each point.

Point	Residual Head.				Remarks.
27	Residual Head at 26	...	...	=	23·58	
	Rise from 26	...	...		20·99	
					2·59	
	Friction in 26-27	...	...		0·30	
	∴ Residual Head	...	...	„	2·29	
14	Residual Head at 19	...	...	„	61·73	
	Fall from 19	...	...		72·45	
					134·18	
	Friction in 19-14	...	...		45·60	
	∴ Residual Head	...	...	„	88·58	Which balances 14 on Red Main.
22	Residual Head at 1	...	...	„	55·67	
	Fall from 1	...	...		40·62	
					96·29	
	Friction in 1-22	...	...		23·60	
	∴ Residual Head	...	...	„	72·69	
20	Residual Head at 22	...	...	„	72·69	
	Fall from 22	...	...		38·45	
					111·14	
	Friction in 22-20	...	...		5·40	
	∴ Residual Head	...	...	„	105·74	Which balances 20 from Blue Main.
4	Residual Head at 20	...	...	„	105·74	
	Rise from 20	...	...		23·91	
					82·83	
	Friction in 20-4	...	...		7·50	
	∴ Residual Head	...	...	„	75·33	Which balances 4 on Red Main.
23	Residual Head at 1	...	...	„	55·67	
	Fall from 1	...	...		12·50	
					68·17	
	Friction in 1-23	...	...		3·10	
	∴ Residual Head	...	...	„	65·07	
24	Residual Head at 23	...	...	„	65·07	
	Fall from 23	...	...		14·15	
					79·22	
	Friction in 23-24	...	...		4·30	
	∴ Residual Head	...	...	„	74·92	

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Rate Abstract.

Laying Cast Iron pipe 4 inch diameter.

Class of Work.	No.	Rate.	Per.	Amount.
(MATERIALS.)		Rs. a. p.		Rs. a. p.
Length 9 feet and weight 161 lbs value of pipe at Bombay ...		5 8 0	Cwt	7 14 6
Railway freight 161 lbs		0 0 $2\frac{1}{2}$	lb	1 14 2
Lead $3\frac{1}{4}$ lbs for joints		0 1 9	„	0 5 8
				10 2 4
		$\frac{10\ 2\ 4}{100}$	=	1 2 0
		Rate per	foot	1 2 0
LABOUR FOR 100 R.F.				
Excavating trenches in mixed soil ...	566 c.ft.	1 8 0	%	8 7 10
Filling in do. do. ...	566 „	0 8 0	„	2 13 3
Fitters	2	1 0 0	day.	2 0 0
Blacksmith	$\frac{1}{3}$	1 0 0	„	0 5 3
Bellows Boy	$\frac{1}{3}$	0 3 0	„	0 1 0
Coolies	5	0 4 0	„	1 4 0
Carriage to site and sundries ...	...	... ...	...	5 0 0
				19 15 4
		$\frac{19\ 15\ 4}{100}$	=	0 3 2
		Materials	...	1 2 0
		Labour	...	0 3 2
		Rate per	foot	1 5 2

Rate Abstract.

Laying Cast Iron pipe $3\frac{1}{2}$ inch diameter.

Class of Work.	No.	Rate.	Per.	Amount.
		Rs. a. p.		Rs. a. p.
(MATERIALS.)				
Length 9 feet and weight ·137 lbs value at Bombay	...	5 8 0	Cwt.	6 11 7
Railway freight 137 lbs... ...	...	0 0 $2\frac{1}{4}$	lb	1 9 8
Lead 3 lbs for joints	...	0 1 9	,,	0 5 3
				8 10 6
		$\frac{8\ 01\ 6}{100}$	=	0 15 4
		Rate per	foot	0 15 4
LABOUR FOR 100 R.F.				
Excavating trenches in mixed soil ...	560 c.ft.	1 8 0	c.ft.	8 6 5
Filling in do. do. ...	560 ,,	0 8 0	,,	2 12 9
Fitters	2	1 0 0	day	2 0 0
Blacksmith	$\frac{1}{3}$	1 0 0	,,	0 5 3
Bellows Boy	$\frac{1}{3}$	0 3 0	,,	0 1 0
Coolies	5	0 4 0	,,	1 4 0
Carriage to site and sundries ...	...	... ...	...	5 0 0
				19 13 5
		$\frac{19\ 13\ 5}{100}$	=	0 3 2
		Materials	...	0 15 4
		Labour	...	0 3 2
		Rate per	foot	1 2 6

Rate Abstract.

Laying Cast Iron pipe 3 inch diameter.

Class of Work.	No.	Rate.	Per.	Amount.
		Rs. a. p.		Rs. a. p.
(MATERIALS.)				
Length 9 feet and weight 112 lbs value of pipe at Bombay	...	5 8 0	Cwt	5 8 0
Railway freight 112 lbs... ...	...	0 0 $2\frac{1}{4}$	lb	1 5 0
Leads $2\frac{1}{2}$ lbs for joints	...	0 1 9	"	0 4 5
				7 1 5
		$\frac{7\ 1\ 5}{100}$	=	0 12 7
		Rate per	foot.	0 12 7
LABOUR FOR 100 R.F.				
Excavating trenches in mixed soil ...	550 c.ft.	1 8 0	%	8 4 0
Filling in do. do ...	550 "	0 8 0	"	2 12 0
Fitters	$1\frac{1}{2}$	1 0 0	day.	1 8 0
Blacksmith	$\frac{1}{4}$	1 0 0	"	0 4 0
Bellows Boy	$\frac{1}{4}$	0 3 0	"	0 0 9
Coolies	4	0 4 0	"	1 0 0
Carriage to site and sundries ...	...	... ...	...	5 0 0
				18 12 9
		$\frac{18\ 12\ 9}{100}$	=	0 3 0
		Materials	...	0 12 7
		Labour	...	0 3 0
		Rate per	foot.	0 15 6

Rate Abstract.

Laying Wrought Iron pipe $2\frac{1}{2}$ inch diameter.

Clalss of Work	No.	Rate.	Per.	Amount.
		Rs. a. p.		Rs. a. p.
(MATERIALS.)				
Piping 100 R.F.	...	0 10 6	Foot	65 10 0
Railway freight 528 lbs... ...	...	0 0 $2\frac{1}{4}$	lb	6 3 1
				71 13 1
		$\frac{71\ 13\ 1}{100}$	=	0 11 6
		Rate per	foot	0 11 6
LABOUR.				
Excavating trenches in mixed soil ...	150 c.ft.	1 8	p.c.	2 4 0
Filling in do. do. ...	150 ,,	0 8	,,	0 12 0
Fitters	$\frac{3}{4}$	1 0	day	0 12 0
Coolies	$2\frac{1}{2}$	0 4	,,	0 10 0
Carriage to site and sundries ...	...	... .	...	3 0 0
				7 6 0
		$\frac{7\ 6\ 0}{100}$	=	0 1 2
		Materials	...	0 11 6
		Labour	...	0 1 2
		Rate per	foot	0 12 8

Rate Abstract.

Laying Wrought Iron pipe 2 inch diameter.

Class of Work.	No.	Rate.	Per.	Amount.
		Rs. a. p.		Rs. a. p.
(MATERIALS.)				
Piping 100 R. F.	...	0 6 3	Foot	39 1 0
Railway freight 395 lbs... ...	...	0 0 $2\frac{1}{4}$	lb	4 10 0
				43 11 0
		$\frac{43\ 11\ 0}{100}$	=	0 7 0
		Rate per	foot	0 7 0
LABOUR FOR 100 R. F.				
Excavating trenches in mixed soil ...	150 c.ft.	1 8 0	=	2 4 0
Filling in " " " ...	150 c.ft.	0 8 0	=	0 12 0
Fitters	$\frac{1}{2}$	1 0 0	day	0 8 0
Coolies	2	0 4 0	"	0 8 0
Carriage to site and sundries ...	...	... .	"	3 0 0
				7 0 0
		$\frac{7\ 0\ 0}{100}$	=	0 1 $1\frac{1}{2}$
		Materials	...	0 7 0
		Labour	...	0 1 $1\frac{1}{2}$
				0 8 $1\frac{1}{2}$
		Rate per	foot.	0 8 0

Rate Abstract.

Laying Wrought Iron pipe $1\frac{1}{2}$ inch diameter.

Class of Work.	No.	Rate.	Per.	Amount.
		Rs. a. p.		Rs. a. p.
(MATERIALS.)				
Piping 100 R. F.	...	0 15 0	foot	31 4 0
Railway freight 319 lbs. ...	...	0 0 $2\frac{1}{4}$	lb	3 11 11
				34 15 11
		$\frac{34\ 15\ 11}{100}$	=	0 5 7
		Rate per	foot	0 5 7
LABOUR FOR 100 R. F.				
Excavating trenches in mixed soil ...	150 c.ft.	1 8 0	=	2 4 0
Filling in ,, ,, ,, ...	150 c.ft.	0 8 0	=	0 12 0
Fitters	$\frac{1}{3}$	1 0 0	day	0 5 3
Coolies	$1\frac{1}{2}$	0 4 0	,,	0 6 0
Carriage to site and sundries ...	...	... .	...	3 0 0
				6 11 3
		$\frac{6\ 11\ 3}{100}$	=	0 1 1
		Materials	...	0 5 7
		Labour	...	0 1 1
				0 6 8
		Rate per	foot	0 6 9

Rate Abstract.

Laying Wrought Iron pipe 1 inch diameter.

Class of Work.	No.	Rate.	Per.	Amount.
		Rs. a. p.		Rs. a. p.
(METERIALS.)				
Piping 100 R.F.	...	0 3 0	Foot	18 12 0
Railway freight 175 lbs... ...	...	0 0 $2\frac{1}{4}$	lb.	2 0 9
				20 12 9
		$\frac{20\ 12\ 9}{100}$	=	0 3 3
		Rate per	foot	0 3 3
LABOUR.				
Excavating trenches in mixed soil ...	150 c.ft.	1 8 0	=	2 4 0
Filling in " " ...	150 "	0 8 0	=	0 12 0
Fitters	$\frac{1}{3}$	1 0 0	day	0 5 3
Coolies	$1\frac{1}{2}$	0 4 0	"	0 6 0
Carriage to site and sundries ...	...	... .	...	3 0 0
				6 11 3
		$\frac{6\ 11\ 3}{100}$	=	0 1 1
		Materials	...	0 3 3
		Labour	...	0 1 1
				0 4 4
		Rate per	foot.	0 4 6